IMPACT OF AGRICULTURAL, INDUSTRIAL AND DOMESTIC WASTE ON GROUNDWATER QUALITY OF GAUTAM BUDH NAGAR DISTRICT, UTTAR PRADESH, INDIA

Thesis
Submitted to Galgotias University for
the Degree of
DOCTOR OF PHILOSOPHY
in Chemistry

By
MEENU AGARWAL
(Enroll. No. 1509303002)

Under the supervision of

Dr. MEENAKSHI SINGH
Professor in Department of Chemistry
SCHOOL OF BASIC & APPLIED SCIENCES
GALGOTIAS UNIVERSITY
GREATER NOIDA (UP)-201308

GALGOTIAS
UNIVERSITY

CERTIFICATE

This is to certify that the thesis entitled "**Impact of Agricultural, Industrial and Domestic Waste on Groundwater Quality of Gautam Budh Nagar District, Uttar Pradesh, India**" submitted by Mrs. Meenu Agarwal for the award of the degree of Doctor of Philosophy in Chemistry to Galgotias University, Greater Noida, is an original piece of work carried out under my supervision. It is a bonafide work to the best of my knowledge and has not been submitted in part or full elsewhere for the award of any degree, diploma or other such purpose. The contributions of other authors have been duly acknowledged at appropriate places in the text of the thesis and are able to place before the examiners for evaluation.

Dated:

Dr. MEENAKSHI SINGH
Prof. Chemistry Department,
Galgotias University,
Greater Noida

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis, entitled "**Impact of Agricultural, Industrial and Domestic Waste on Groundwater Quality of Gautam Budh Nagar District, Uttar Pradesh, India**" in fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Chemistry and submitted in Galgotias University, Greater Noida, is an authentic record of my own work carried out under the supervision of Dr. Meenakshi Singh.

The matter embodied in this thesis has not been submitted by me for the award of any other degree of this or any other University/Institute.

Dated:

MEENU AGARWAL
Galgotias University
Greater Noida

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dated:

Dr. MEENAKSHI SINGH
Prof. Chemistry Department,
Galgotias University,
Greater Noida

ABSTRACT

Groundwater is one of the supreme valuable natural resources present on earth. It is important for the sustainability of all living organisms, most ecological systems, human health, food production and economic development. Today industrialization combined with fast growing population is responsible for the overexploitation of water aquifers. Ground aquifers are increasingly being contaminated with sewage, agricultural chemicals, oils, heavy metals, detergents and many other synthetic products. Statistics of quality data and understanding of aquatic systems is necessary for the conservation and remediation of underground water reservoir.

In the current study, the overall quality of groundwater available in district Gautam Budh Nagar has been assessed by evaluating its physico-chemical characteristics and heavy metals concentration. An effort has been made to find spatio-temporal variation in groundwater quality in three years of consecutive study. Appropriateness of groundwater for drinking and irrigation purpose was analysed by comparing the analytical results with the standards of BIS, WHO and USDA. Further, attempt has also been made to establish the possible sources (agricultural runoff, industrial effluent, municipal wastewater) of groundwater pollution in eleven villages of Gautam Budh Nagar district. To understand the quality of subsurface water, study area was divided into three zones on the basis of land use pattern; Agricultural zone, Industrial zone, Residential zone. Various statistical and graphical methods were inculcated to interpret the analytical results. A survey was also conducted among the residents of study area to find the health status and the issues related to groundwater quality. Linear combination of physico-chemical analysis of groundwater and waste water samples with GIS map was very effective in assessing pollution risks to ground aquifers and source of contamination. Finally a novel approach to remove excess of fluoride ions from aqueous solution using marble slurry adsorbent was also done.

Twenty two samples of groundwater and thirteen waste water samples from major drains were collected in the pre-monsoon season (in the month of June) and post-monsoon season (in the month of October) of consecutive three years - 2016, 2017, 2018. These samples were analysed for the major cations, anions, and heavy metals by following standard procedures as prescribed by APHA (2012).

The present study revealed that groundwater quality in eleven villages of district Gautam Budh Nagar was confronted with high ionic content as well as heavy metal contamination. Heavy load of pollutants were present in waste water due to various anthropogenic activities such as agricultural runoff, effluents of steel-iron industry, rice mill, paper industry, fabric dyeing industry and municipal discharge. Leaching of hazardous chemicals, present in waste water added a significant amount of it in ground aquifers. Results of physico-chemical analysis, metal analysis and water quality index revealed that groundwater of industrial zone of study area was highly polluted and if suitable precautions are not taken immediately, it will adversely affect groundwater quality of other regions of study area. After analyzing seasonal variation on pollution load of groundwater, it is concluded that contamination was maximum in pre-monsoon season and recharging of ground aquifer from rainwater decreased it due to dilution. Health survey revealed that carcinogenicity and gastro-intestinal disorders were common among inhabitants at all the sites. The study shows that marble slurry was a cost effective as well as highly effective adsorbent for defluoridation of water. The optimum defluorosis of 89.3%, from aqueous solution was found to be at adsorbent dose of 15 gm/L, contact time of 50 minutes and in the pH range of 6.12 to 7.01.

In study area, groundwater is the only source of water for various domestic, industrial and irrigational requirement hence short term and long term water quality management, regular water monitoring and restoration programs should be designed to protect ground aquifers. The study concluded that there is a need to undertake awareness campaigns, effluent regulations, development of necessary infrastructures and to check dumping of pollutants under EIA and EMS.

Keywords- Gautam Budh Nagar, Physico-chemical analysis, Groundwater, Wastewater, Pre-monsoon season, Post-monsoon season, Water quality index.

ACKNOWLEDGEMENT

For the past 4 years, I was engaged in a fruitful exercise which left me richer by several reality and experiences. My knowledge enhancement is mainly due to the invaluable guidance, encouragement and assistance from numerous peers who have contributed a lot towards shaping this thesis.

On the outset, I would like to express my sincere gratitude and thanks to my guide **Dr. Meenakshi Singh**, Professor, Chemistry Department, Galgotias University. She has been a tremendous mentor. I would like to thank her for encouraging my research and for allowing me to grow as a research scientist. Her advice on both research as well as on my career has been priceless. Her observations and comments helped me to steer the research in the right direction and to move forward with the investigation.

I am grateful to **Dr. Pradeep Kumar**, PVC, Galgotias University, **Dr. A.K. Jain,** DSW, **Dr. Ratna** for their brilliant suggestions which enabled me to complete my research work.

I am very much thankful to **Dr. Jakir Hussain**, Research officer & Head (National River water quality Laboratory, New Delhi) for contributing significantly to the research work and to conduct different analytical test in the laboratory. He was very cooperative and helped me every now and then throughout the journey towards completion of my project. Same time my sincere thanks to **Mr. Rajesh Kumar, Dr. Kamalneet Kaur, Dr. Neeru Tiwari, Mr. Nitish Kumar** and **Mr. Ashutosh Tripathi** of NRWQL to support me to conduct the testing.

I am thankful to **Mr. Sachin Gahlot** to support me on IT front and **Mr. Kiranpal** to assist me in collecting the water samples of different villages.

I express my deepest gratitude to **Adv. K.K. Bhati, Prof. Devender Nagar, Mr. Rame Nagar** & **Adv. Surinder** to support me in the field work during my research and in collecting information from local villagers.

Last, but not least, I would like to dedicate this thesis to my family, my spouse **Rahul**, daughter **Anushka** & Son **Ekagrah** for their love, patience, and understanding. They allowed me to spend most of the time on this thesis and encourage me always to deliver my best.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PUBLICATIONS

- Meenakshi Singh, Meenu Agarwal 2016. Groundwater Analysis in North India: A Review". International Journal of Engineering and Allied Sciences. Vol. 2, issue 2. ISSN: 2455-2054
- Meenakshi Singh, Meenu Agarwal 2017. Characteristics and Adsorption capacities of Biosorbents for removal of Cr (VI) from aqueous solution: A Review". Journal of Current Research. Vol. 9, issue 5, pp. 51087-51093. ISSN: 0975-833X
- Meenu Agarwal, Meenakshi Singh, Jakir Hussain 2019. Assessment of Groundwater with special emphasis on Nitrate contamination in parts of Gautam Budh Nagar district, Uttar Pradesh, India". Acta Geochimica. 38, 703–717. https://doi.org/10.1007/s11631-018-00311-z.
- A paper titled "Evaluation of Groundwater Quality for Drinking Purpose using Different Water Quality Indices in Parts of Gautam Budh Nagar District, India" has been accepted in Asian Journal of Chemistry.

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
APHA	American Public Health Association
BIS	Bureau of Indian Standards
CCME WQI	Canadian Council of Ministers of the Environment Water Quality Index
CGWB	Central Ground Water Board
CSSRI	Central Soil Salinity Research Institute
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMS	Environmental Management Systems
GBN	Gautam Budh Nagar
GIS	Geographical Information Systems
GWQI	Groundwater Quality Index
KI	Kelly Index
MH	Magnesium Hazard
Na%	Sodium Percentage
PI	Permeability Index
ppb	Parts per billion
ppm	Parts per million
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
St. Dev.	Standard Deviation
TA	Total Alkalinity
TDS	Total Dissolved Solids
TH	Total Hardness

UNEP	:	United Nations Environment Programme
UNICEF	:	United Nations Children's Emergency Fund
USDA	:	U.S. Department of Agriculture
WAWQI	:	Weighted Arithmetic Water Quality Index
WHO	:	World Health Organization
WQI	:	Water Quality Index

*All references are given in alphabetical order

Chapter 1

INTRODUCTION

1.1 GENERAL

Water is one of the crucial component of environment which is required for the existence of life on the planet. Water is not only the vital constituent of all living organisms, but also essential for the sustainability of the mankind on earth. According to World Health Organization (WHO), clean and safe water especially drinking water is a fundamental right of a person and it is a part of policies made for protection of human health (WHO, 2011). Our planet is called blue planet as 71% of earth crust is covered with water. Out of total water present on earth, 97.4% is saline water and present in oceans & seas while only 2.6% is fresh water. Out of this fresh water 1.98% is present in icecaps and glaciers, 0.59% is groundwater and rest of 0.001% is present in atmosphere (as water vapours), rivers, plants and animals.

From ancient time rivers and streams have an important role in civilization of the mankind. Many civilizations in world – the Mesopotamian civilization (Tigris & Euphrates Valley), the Egyptian civilization (Nile river), the Harappan civilization (Indus river), and the Chinese civilization (Yellow river) developed around rivers. For centuries, humans are using rivers and streams to fulfill their own requirement. Over a period of time, nature of rivers has been changed due to over-exploitation of their natural resources. Humans control the natural flow of river by making dams and unauthorized settlements. They also use rivers as a disposal site of wastes. Due to exploitation of riverine wealth, a decline in surface water quality has been observed. Now at most of the places on earth, river water is not fit for human consumption, irrigation, recreational, industrial and other purposes. Fresh water requirement is increasing successively and now water scarcity is a big problem in every country. Quantity and quality of fresh water, are the major issues for everyone. Blind usage of fresh water resources led to water crisis in many parts of world.

India is facing a fresh water crisis due to inappropriate utilization of water resources. With different intensity, water crisis in many states of India is very likely seen in summer season. Day by day human water requirement is increasing and surface water is no longer available in adequate quantity & quality hence new sources of fresh water are required (National Research Council, 1999).

Groundwater is another source of fresh water. It is a significant component of water cycle. Groundwater is the major consideration for all socio economic, cultural, industrial and technical development. Groundwater is preferably used in every sector of society due to its all-time availability at every place and at low cost. Due to geographical and environmental conditions, fresh water resources are not evenly distributed among different continents. According to United Nations Environment Programme (UNEP), although Asia is the biggest continent in world in terms of population (60% of world's total population) has only 36% of world's total fresh water resources. In India out of total extracted groundwater, 89% is utilized for irrigation, 9% for domestic purposes and rest of 2% for industrial use (CGWB, 2015). A stress on ground aquifers is increasing due to indiscriminate utilization. Non-scientific usage of ground aquifers, less rain fall and ignorance about groundwater recharging techniques are few reasons for decline of groundwater level. Lowering of groundwater level led to deleterious effects on groundwater quality.

In last five decades, due to increasing rate of industrialization and urbanization, human requirement of water has been increased tremendously. Ground water is greatly affected by human and industrial activities. The waste water generated from domestic and industrial activities is discharged directly on open land or in drains. This contaminated waste water gets percolate into ground aquifers and contaminate it. It is a well-recognized fact that the groundwater quality of both urban and rural areas is polluted. Water contamination problem is approaching a major crisis levels around the world, causing death and disease in the developing world (Olajire & Imeokparia, 2000; Wu & Sun, 2016; Qasemi et al., 2018). According to the Global Water Supply and Sanitation Assessment 2000 report jointly published by WHO/UNICEF, nearly 80% of disease are water borne and every third life loss is due to contaminated drinking water. Due to contaminated water, overall production economy is reduced by 10%. Groundwater pollution specifies the deterioration in quality of natural water by various sources. Most of the times pollutants in groundwater enter through percolation of harmful substances from waste water. The source of waste water can be agricultural, industrial or municipal.

1.2 PRINCIPAL SOURCES OF GROUNDWATER POLLUTION

The principal sources of groundwater pollution are classified into four categories.

- Agricultural Sources
- Industrial Sources
- Municipal Sources
- Miscellaneous Sources

1.2.1 Agricultural Sources

- Irrigation return flow

The amount of irrigation water which is not consumed by crop, drains to water channels or percolates to ground aquifers, is termed as irrigation return flow. Amount of irrigation return flow depends upon the geographical conditions of area, soil texture, type of crop, amount of rainfall and irrigation method.

- Fertilizers and Soil amendments

A portion of applied fertilizers leaches from the soil due to irrigation water and rainfall. Harmful chemicals from these fertilizers mix with groundwater and contaminate it. The leaching of nitrate through soil is more prevalent in irrigated agricultural area. Irrigation of crop through river, canal and groundwater add a significant quantity of ions in the soil. Excessive amount of nitrogen fertilizers cannot be consumed by the crop. Due to high solubility of nitrate, it can easily percolates down in soil layers (Kundu & Mandal, 2009).

Soil amendments are required to enhance fertility of soil for good crop. Generally lime, gypsum and sulfur are added to soil for balancing soil properties. A significant quantity of these added chemicals percolates in soil and contaminates groundwater.

- Pesticides

Application of pesticides is requisite in agricultural areas. Leaching of applied pesticides is also another source for the contamination of groundwater. A trace amount of pesticides in water used for drinking purpose, led to serious health issues (Menchen et al., 2017).

1.2.2 Industrial Sources

- Liquid wastes

Waste water originated from various industries is directly dumped into ground aquifers or discharged into nearby drains, ponds or water channels. From these sources, waste water migrates and contaminate ground aquifers. Industrial waste water contains a large amount of different heavy metals. These metals enter into the ground aquifers and contaminate it. These metals are non-biodegradable and remain in the environment for a longer period of time (Bhutiani et al., 2016; Selvakumar et al., 2017).

- Tank and Pipe line leakage

A large number of chemicals are stored in underground tanks for industrial purposes. Fuels are also stored beneath the earth surface. Pipelines are used to carry these chemicals and fuels to the utility point. Any structural failure in storage tanks and pipelines can led to accidental leakage of chemicals. This leakage becomes a source of contamination to ground aquifers. Faulty installation, inadequate operating and improper maintenance are the major reasons for the leakage of chemicals of underground tank into the environment.

- Mining Activities

Mining activities are also a source of groundwater pollution. Hydrochemistry of groundwater in mining areas is determined by the weathering of rocks, metals to be extracted, mining process and mineral processing unit. Mining process adds a significant amount of metals in groundwater of that area (Singh et al., 2018).

- Oil field brines

Brine is produced during the production of oil and gas. Brine is containing many dissolved inorganic salts like sodium chloride, calcium chloride, calcium bromide, calcium carbonate, potassium chloride, formate and metals. The use this brine for various purposes (de-icing of roads, for dust suppression etc.) increased the sodium, potassium, chloride and total dissolved solids of groundwater (Tasker et al., 2018; Wen et al., 2019).

1.2.3 Municipal Sources

- Landfills

Landfills are the most widely used method for municipal solid waste (MSW) disposal. A complex mixture of chemicals called leachate originates from these landfills sites. Leachate is a potential pollutant affecting natural resources. Many researchers studied the quality of groundwater near the landfills sites and concluded that percolation of leachate causes groundwater pollution (Liu et al., 2010; Han et al., 2014; Abd-El- Salam & Abu-Zuid, 2015; Naveen et al., 2016; Chonattu et al., 2016;

Koda et al., 2017; Negi et al. 2018; Parth & Mukherjee, 2019). A remarkable concentration of insect repellent DEET (N,N-Diethyl-m-toluamide, upto 1.8 µg/L) was reported in groundwater of Kabwe of Zambia. Triclosan, THMs, herbicides, insecticides and chlorinated solvents were also observed in many samples of Kabwe, Zambia. Contamination of groundwater of Kabwe was more prevalent within shallow wells located in regions having houses without proper sanitation system and open disposal of household garbage (Sorensen et al., 2015).

- Sewer Leakage

Leakage of sewerage water increases biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate content and bacterial contamination of groundwater. In addition to this, heavy metals (As, Cd, Cr, Co, Cu, Fe, Pb, Mn & Hg) also introduced in groundwater through sewer placed in industrial zone (Dvory et al., 2018).

1.2.4 Miscellaneous Sources

- Saline water Intrusion

In coastal areas, intrusion of saline water in ground aquifers increases the salinity of groundwater. Highly saline groundwater is found in areas near to sea & oceans. In deep ground aquifers, upward movement of natural saline water causes salinity problem. In case of shallow aquifers the same can take place from surface water discharges while in coastal aquifers the process is through an invasion of sea water.

- Septic tanks and Cesspools

Very commonly distributed sources for pollution of groundwater are septic tanks and cesspools. Domestic sewage introduce significant quantity of ions to subsurface water. Under natural conditions, bacteria and virus are removed in soil layers. Phosphorous is generally retained by the soil, but a substantial amount of nitrate enters into ground aquifers.

- Spills and Surface discharges

Accidental discharge of liquids on earth surface by any unavoidable means (during transportation, leakage from container carrying liquid, leakage from pipes/valves, can percolate down to groundwater levels. Chemicals present in discharged liquid enhances ions concentration in groundwater or contaminate it.

1.3 MITIGATION OF GROUNDWATER CONTAMINATION

Groundwater contamination is a serious problem because of the presence of variety of pollutants, their reactions with each other and alteration in groundwater quality. The fate of pollutants in groundwater is very difficult to estimate. Once pollutants enter the ground aquifers, it is very difficult to restore its quality. Counteraction should be immediately installed to prevent further damage to groundwater quality. The following reasons explain the assertion.

1. The effects of groundwater pollution are visible only after contamination has introduced in it.
2. Ground aquifers are inaccessible therefore it is impossible to purify it in its natural habitat.
3. Time and energy consumption is very high for purification of groundwater.
4. After terminating the source of contamination, groundwater takes a long time to reconstruct it natural quality.
5. All water resources are inter-connected in hydrological cycle, and hence contamination can enters to ground aquifers through other surface water resources.
6. Ground aquifers supply water to a large population for drinking and cooking purpose. When it becomes contaminated, immediate, alternative source of fresh water is not available.
7. Ground aquifers are also used for irrigation water for a large crop land. Once the crop gets affected by contamination of irrigation water, it adversely affects a large group of population.

Above facts signifies that the mitigation of groundwater contamination is very expensive and tedious process. It is an urgent need to specify the source of contamination in ground aquifers so that we can immobilize or destroy groundwater contaminants. The effect of waste water entering the ground aquifers should also be determined.

Current study area is a region of alluvial plain and in last two decades, for the economic growth of this area, a large number of manufacturing industries are established here or shifted from nearby areas of Delhi and Ghaziabad. Various types of industries; iron & steel industry, rice mills, cement industry, paper industry, chemical industry etc. are running in district Gautam Budh Nagar. The waste water of these industries containing the hazardous materials is dumped in nearby water bodies or directly into the ground aquifers without any treatment. Over a period of time toxic substances, present in industrial wastes, contaminate the surface water as well as groundwater. In this regard, the present study has been focused on quality assessment of groundwater of Gautam Budh Nagar District and its suitability for drinking and irrigation purposes. The details of this investigation are presented in various chapters of the thesis.

1.4 OBJECTIVE OF CURRENT RESEARCH WORK

To study the groundwater quality of Gautam Budh Nagar district of Uttar Pradesh, following objectives are kept for consideration.

1. To determine the general physico-chemical properties of groundwater in agricultural area, industrial area and residential area.
2. To determine the concentration of selected toxic heavy metals and compare the results with standard guidelines of BIS and WHO.
3. To find out the acceptability of groundwater for drinking purpose.
4. To find out the acceptability of groundwater for irrigation purpose.
5. To investigate the effect of seasonal variation on groundwater quality.
6. To investigate the effect of waste water on groundwater quality.
7. To propose the Water Quality Index so as to multi layered concept of water quality can be communicated to society in numerical term.
8. To prepare groundwater quality map for district.
9. To Mark safe groundwater areas.

The current work is a maiden attempt to describe impact of agricultural, industrial and residential waste water on groundwater quality. Due to scarcity of literature on ground water chemistry in current study area and limited financial and other resources to undertake detailed field investigation, certain short-comings are inevitable. However, it is felt that the thesis may prove useful in the field of hydrochemistry and understanding the problems of groundwater pollution.

REFERENCES

1. Abd El-Salam M.M., Abu-Zuid G.I., 2015. Impact of landfill leachate on the groundwater quality: A case study in Egypt. Journal of Advanced Research. 6, 579–586.
2. Bhutiani R., Kulkarni D.B., Khanna D.R., Gautam A., 2016. Water Quality, Pollution Source Apportionment and Health Risk Assessment of Heavy Metals in Groundwater of an Industrial Area in North India. Exposure and Health. 8, (1) 3-18.
3. Central Ground Water Board, 2015. Annual Report 2014-2015.
4. Chonattu J., Prabhakar K., Pillai H.P.S., 2016. Geospatial and Statistical Assessment of Groundwater Contamination Due to Landfill Leachate—A Case Study. Journal of Water Resource and Protection. 8, 121-134.
5. Dvory N.Z., Kuznetsov M., Livshitz Y., Gasser G., Pankratov I., Lev O., Adar E., Yakirevich A., 2018. Modeling sewage leakage and transport in carbonate aquifer using carbamazepine as an indicator. Water Research. 128, 157-170.
6. Han D., Tong X., Currell M.J., Cao G., Jin M., Tong C., 2014. Evaluation of the impact of an uncontrolled landfill on surrounding groundwater quality, Zhoukou, China. Journal of Geochemical Exploration. 136, 24–39.
7. Koda E., Miszkowska A., Sieczka A., 2017. Levels of Organic Pollution Indicators in Groundwater at the Old Landfill and Waste Management Site. Applied Sciences. 7, 638. doi:10.3390/app7060638
8. Kundu M.C., Mandal B., 2009. Agriculture activities influence nitrate and fluoride contamination in drinking groundwater of an intensively cultivated district in India. Water Air and Soil Pollution. 198, (1-4) 243-252.
9. Liu H., Liang Y., Zhang D., Wang C., Liang H., Cai H., 2010. Impact of MSW landfill on the environmental contamination of phthalate esters. Waste Management. 30, (8-9) 1569-1576.
10. Menchen A., Heras J.D., Alday J.J.G., 2017. Pesticide contamination in groundwater bodies in the Júcar River European Union Pilot Basin (SE Spain). Environmental Monitoring Assessment. 189, 146.

11. National Research Council, 1999. Our Common Journey: A Transition Toward Sustainability. Washington, DC: The National Academies Press. Chapter 4. Environmental Threats and Opportunities. https://doi.org/10.17226/9690
12. Naveen B.P., Mahapatra D.M., Sitharam T.G., Sivapullaiah P.V., Ramachandra T.V., 2016. Physico-chemical and biological characterization of urban municipal landfill leachate. Environmental Pollution. http://dx.doi.org/10.1016/j.envpol.2016.09.002
13. Negi P., Mor S., Ravindra K., 2018. Impact of landfill leachate on the groundwater quality in three cities of North India and health risk assessment. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-018-0257-1
14. Olajir A.A., Imeokparia E.E., 2000. A Study of the water quality of the Osun River: metal monitoring and geochemistry. Bulletin of Chemical Society of Ethiopia. 14, (1) 1-8.
15. Parth V., Mukherjee S., 2019. Health Risk Assessment of Some Dominant Heavy Metal Species Detected in Subsurface Water Near Kolkata MSW Landfill Site. In: Kundu R., Narula R., Paul R., Mukherjee S. (eds) Environmental Biotechnology For Soil and Wastewater Implications on Ecosystems. Springer, Singapore.
16. Qasemi M., Afsharnia M., Zarei A., Farhang M., Allahdadi M., 2018. Non-carcinogenic risk assessment to human health due to intake of fluoride in the groundwater in rural areas of Gonabad and Bajestan, Iran: A case study. Human and Ecological Risk Assessment: An International Journal.
    DOI: 10.1080/10807039.2018.1461553
17. Selvakumar S., Chandrasekar N., Kumar G., 2017. Hydrogeochemical characteristics and groundwater contamination in the rapid urban development areas of Coimbatore, India. Water Resources and Industry. 17, 26-33.
18. Singh U.K., Ramanathan, A.L., Subramanian, V., 2018. Groundwater chemistry and human health risk assessment in the mining region of East Singhbhum, Jharkhand, India. Chemosphere. 204, 501-513.

19. Soresen J.P.R., Lapworth D.J., Nkhuwa D.C.W., Stuart M.E., Gooddy D.C., Bell R.A., Chirwa M., Kabika J., Liemisa M., Chibesa M., Pedley S., 2015. Emerging contaminants in urban groundwater sources in Africa. Water Research. 72, 51-63.
20. Tasker T.L., Burgos W.D., Piotrowski P., Castillo-Meza L., Blewett T.A., Ganow K.B., Stallworth A., Delompr´e P.L.M., Goss G.G., Fowler L.B., Vanden Heuvel J.P., Dorman F., Warner N.R., 2018. Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads. Environmental Science & Technology. 52, 7081–7091.
21. Wen T., Agarwal A., Xue L., Chen A., Herman A., Li Z., Brantley S.L., 2019. Assessing changes in groundwater chemistry in landscapes with more than 100 years of oil and gas development. Environmental Science Processes & Impacts. 21, 384-396.
22. World Health Organization (WHO) (2011) Guidelines for drinking-water quality, Fourth editition, World Health Organisation, Geneva.
23. World Health Organization (WHO), United Nations Children’s Fund (UNICEF), 2000. Global Water Supply and Sanitation Assessment 2000 Report. WHO, Geneva and UNICEF, New York.
24. Wu J., Sun Z., 2016. Evaluation of Shallow Groundwater Contamination and Associated Human Health Risk in an Alluvial Plain Impacted by Agricultural and Industrial Activities, Mid-west China. Exposure and Health. 8, (3) 311-329.

Chapter 2

REVIEW OF LITERATURE

2.1 GENERAL

Water is a vital element of our environment. Water is second most important necessity for every living organism. Availability of clean and safe water is prime requirement for every human being. As clean surface water is no longer available for everyone, groundwater is another source to satisfy the demand. Due to increasing urbanization and industrialization, a stress is developed on ground aquifers. It results into deterioration of groundwater quantity and quality. A large amount of solid and liquid wastes is generated through industrial, agricultural and domestic activities. This waste contains a variety of chemicals and improper disposal of it causes environmental pollution. Directly or indirectly the hazardous chemicals present in waste, enters the ground aquifers and contaminate it. High alkalinity and hardness, elevated concentration of fluoride, nitrate, heavy metals and organic matters in groundwater causes serious health issues (Ngah et al., 2012; Nowak et al., 2012). Akinbile & Yusoff, (2011) reported that dumping of solid industrial wastes at landfill sites caused contamination of groundwater at that place. It was also reported that total dissolved solids (TDS) of subsurface water decreased as the distance from landfill site increased. Leachates generated from these landfill sites contain a large quantity of metal ions (Aderemi et al., 2011). The groundwater contamination level in India was studied by many researchers and at many places it needs urgent remedial measures (Nagamani et al., 2015; Bhattacharya et al., 2013). Industrial effluent of most of the type of industries (like cement, paint, automobiles, textile, paper, leather etc.) contain hazardous metals. The improper disposal of these industrial effluents in unscientific manner allows to leave a large quantity of heavy metals in the ecosystem. These metals mixes with rain water and percolate down through the soil layers and reach to ground aquifers. As these metals are persistent and highly soluble in water, hence reside in subsurface environment for a long time (Karthika et al., 2015). From the intake of contaminated water, these metals can easily entered into the body of living organisms causing acute and chronic both type of diseases.

Northern part of India is heavily populated region due to its diverse climate, heavy rainfall, fertile land and perennial rivers. A great number of industries have been established here due to availability of raw materials, man power and good transportation system. Due to increasing industrialization and urbanization, a lot of wastes is produced in this region. Agriculture is also very high in this region (Uttar Pradesh, Haryana and Punjab). Due to farming, a large quantity of agricultural waste water is also generated in this region. Many researchers throughout the world studied the effects of waste water on groundwater quality (Balakrishnan et al., 2008; Tariq et al., 2008; Azom et al., 2012; Singh & Rao, 2013; Kumar, 2014; Olaoye & Oladeji, 2015; Matta et al., 2016; Selvakumar et al., 2017; Abdalla & Khalil, 2018; Kanagaraj & Elango, 2019). Groundwater quality of few villages of Haryana was analysed by Meenakshi et al., (2004) and reported high fluoride concentration in groundwater causing dental fluorosis. Groundwater quality of Najafgarh region was also found poor (Adhikary et al., 2010). Effect of effluent, coming from Panipat sugar mill of Haryana, on groundwater quality, was studied by Yadav & Daulta, (2014). They concluded that biological oxygen demand, dissolved oxygen and alkalinity of groundwater was very high in that area.

Kumar et al., (2016) studied the effects waste water of dairy and domestic sewage on groundwater quality of Adil Nagar, Lucknow. Studies were carried out in summer, monsoon & winter season of 2014. Results of study revealed that pH, alkalinity, total hardness, PO_4, SO_4 and Cl of groundwater were higher in summer season whereas nitrate concentration increased after precipitation (NO_3; 17.12 mg/L). The metal content of analysed samples were higher in winter season except copper and manganese. They concluded that dumping of dairy wastes and domestic effluents was contaminating ground aquifers.

Kumar et al., (2017) investigated the distribution pattern of chemical parameters of groundwater in the Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India. They also studied source of groundwater contamination and polluted water borne diseases among the local residents. The results of their study concluded that the concentration of few toxic metals such as Al, As, B, Cd, Cr, Mn, Pb and U exceeded the standard values of WHO (2011) and BIS (2012) at some locations while Ba, Cs, Cu, Fe, Ga, Ge, Li, Mo, Ni, Rb, Sb, Se, Sr, Th, Ti, V, W, Y and Zn were well below the standard values.

In agricultural areas, out of various groundwater pollutants, nitrate is a major pollutant (Rahmati et al., 2015; Wu & Sun, 2016; Asadi et al., 2017). A number of researchers investigated the occurrence and distribution scenario of subsurface nitrate contamination in India. In the studies, both type of source of nitrate pollution were identified - anthropogenic and geogenic. Vertical and lateral movement of nitrate in soil layers was studied by Rao, (2006) in Srikakulam district of Andhra Pradesh. In groundwater samples nitrate concentration was detected upto 450 mg/L. Nitrate leaching in that area was determined by the geological composition of clay and sand. Agricultural source of nitrate in groundwater (7.10 – 82.0 mg/L) was evidenced by studies carried out in the arid or semi-arid area in Thar desert of India. Similarly disposal of livestocks excreta increased groundwater nitrate level (Singh & Sekhon, 1976). Central Ground Water Bureau (CGWB, 2010) studied the groundwater nitrate contamination at district level all over India. The results of the study concluded that in many states of India (Andhra Pradesh, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan and Uttar Pradesh) groundwater nitrate contamination level was far beyond the standard limit of BIS.

2.2 REVIEW OF INTERNATIONAL STATUS OF GROUNDWATER QUALITY

Hakim et al., (2009) evaluated the suitability of subsurface water for domestic, irrigation, and industrial activities in Chiribandar in Dinajpur district of Bangladesh. After analyzing the results, they concluded that except at few places water quality was suitable for drinking, irrigation, and industrial purposes. The nitrate and phosphate concentration was very less. In terms of boron and SSP, groundwater samples were good to excellent type. All the analysed sample were moderately saline and low alkaline. TDS and RSC values of groundwater samples were also suitable for irrigation. Arsenic concentration was less than the standard limit.

Groundwater quality is influenced by the land use pattern and human activities running in the area. **Lerner & Harris, (2009)** suggested that commercial and agricultural activities running in a region should be according to the geology of that area and environmental conditions. **Jiang et al., (2009)** documented that water quality of underground river system of Nandong in China, was affected by factors- contamination from human activities, interaction between water and limestone/ dolomite rich rocks.

Aghazadeh & Mogaddam, (2010) evaluated the groundwater quality of Oshnavieh plain in West Azarbaijan province of Iran, for drinking and irrigation. Analytical results revealed that groundwater quality was governed by the lithology of that area and water was appropriate for human consumption and irrigation of crop land.

Sayadi et al., (2011) investigated the groundwater quality of Anar city, Kerman, Iran for utilization in drinking and irrigation. Groundwater samples were collected in the consecutive seasons, i.e. spring, summer, autumn and winter in the year of 2010. Analytical results showed SAR values from 54.78 to 61.16 in the spring and summer seasons respectively. The irrigation water quality in the study area was categorized as very poor with reference to SAR and strongly suggested that groundwater was not suitable for human consumption.

Ezekwe et al., (2012) studied the effects of contaminated water on health of residents of the Lokpaukwu, Lekwesi and Ishiagu mining areas of south-eastern Nigeria. Sampling of twenty seven groundwater samples was done in June 2007 and February 2008. All the samples were inspected for water quality parameters and heavy metals. Analytical results revealed that most of the analysed samples i.e. 73% exceeded the standard value of iron given by WHO (0.3 mg/L). In nearly 41% of samples, manganese was analysed beyond the standard limit (0.4 mg/L). Mental related illness was very likely seen among the residents of that area. They concluded that prolonged consumption of manganese rich water results into mental illness. They also recommended that groundwater system of mining area was very critical and needs attention.

Matini et al., (2012) examined the temporal variation in subsurface water quality in southwestern Brazzaville, Congo. They studied the groundwater samples twice in a year (March to April 2008 & July to August 2008). Analytical results revealed that most of the parameters (except pH and NO_3) had lesser value in dry season. In rainy season, groundwater hydrochemical facies was Mg-Ca-HCO_3 and in dry season it was Na-HCO_3. The natural factors governing the composition of groundwater were weathering of silicate & carbonate from rocks, ion exchange between water & rocks. High concentration of HCO_3 in groundwater in rainy season was due to silicate weathering.

Wirmvem et al., (2013) studied the chemistry of surface and subsurface water in the Ndop plain, North West Cameroon for the suitability for drinking and irrigation. About 69% of samples have acidic nature of water. Conductivity value (less than 282 µS/cm) and TDS value (less than 183 mg/L) of groundwater samples were very less showing less dissolution of minerals. The increasing order of ion concentrations was K < Mg < Ca < Na (for cations) and SO_4 < Cl^-< NO_3 < HCO_3 (for anions). All the analysed ions were well below the corresponding standard value given by WHO. The analysed water was suitable for irrigation.

The impacts of the urban and industrial effluent on quality of surface and subsurface, in Annaba area of Algeria during 1999-2007 was studied by **Bougherira et al., (2014).** The groundwater showed a high electric conductivity (> 560 µS/cm), a high chloride content (> 6000 mg/L) and a high sodium concentration (420 mg/L). The concentration of chromium was 0.02 to 1.25 mg/L in the wells near to industries. River Meboudja in Annaba was acting as a diffuse source of contaminations all along its course.

Jesmanitafti et al., (2014) investigated the impacts of using wastewater coming from industrial states for irrigation in industrial state of Shokouhieh in Qom Province in central of Iran. The water quality parameters and heavy metals were examined in inputting wastewater into refinery, outputting wastewater and soil of that area. Rapid Impact Assessment Method (RIAM) and Entropy Method were used to assess the results. The results of both the methods revealed that using of wastewater effluent for irrigation of green area results into entrance of chemical pollutants (nitrate) into groundwater. Soil of industrial area became saline and toxic. The results of study revealed that environment of industrial state was not safe for workers and labors.

Liu et al., (2014) investigated metal concentration in wheat plants near the Fengfan lead- acid battery factory in Baoding, China. The concentration of heavy metals in agricultural soil (As, Cd, Cr, Cu, Mn, Ni, Pb and Zn) and in wheat plants at progressive level of growth (Cd, Pb and Zn) were investigated. The results of the study revealed that the mean content of the studied metals in the surface soils were all lower than the guideline value. However the contamination factor for Pb ranged from 2.8 to 5.3. The elements Cd, Pb and Zn entered the soil through atmospheric deposition.

Aly et al., (2014) used water quality index method for analyzing the drinking suitability of groundwater before and after purification treatment in Hafar Albatin, Saudi Arabia. They also studied the fitness of untreated subsurface water for irrigation purpose. Analytical results concluded that most of the untreated wells came under unsuitable category (class V), 39% of samples were having very poor water (class IV), and 14% fell under poor category of water (class III). After treatment quality of groundwater have been improved to poor category (class III) and good category (class II). From Durov and Piper plot, major hydrochemical facies were sodium chloride and calcium sulfate–chloride.

Pourghasemi & Beheshtirad, (2015) generated groundwater potential map (GPM) in the Koohrang Watershed, Chaharmahal-e-Bakhtiari Province, Iran. For study purpose, 864 groundwater samples were collected and analysed. The study was carried out in three stages – preparation of data, plotting of potential map and validation of model using receiver operating characteristic (ROC) curve. The results of study were helpful for engineers in management of water resources and land-use planning.

Cai et al., (2015) assessed the adverse health impacts due to heavy metals in residents, near Tonglushan mine in Hubei, China. Soil, crop, well water and fish samples were investigated for Cu, Cd, Pb and As. Results of the study indicated that soil near the mine was metal contaminated. Groundwater samples had high concentration of Cd, Cu and As. The mean estimated daily intakes of Cd and As metal were higher than the corresponding provisional tolerable daily intake.

Wongsanit et al., (2015) studied the nitrate pollution in subsurface water and its negative health impacts on population at lower Mae Klong river basin of Thailand. Hazard quotient was calculated and health risk maps were generated on the basis of it. US Environmental Protection Agency guidelines were used for standardization. Analytical results revealed that application of nitrate rich fertilizers was responsible for elevated concentration of nitrate in groundwater. It was advised that nitrogen management practices should be adopted by the farmers to save the quality of groundwater.

Rasool et al., (2016) studied the metal contamination in the tube well water of Jallah Jeem and DurPur, Punjab in Pakistan. The source of contamination and associated health risk to local residents was also studied. Analytical results revealed that mean concentration iron, cadmium, lead, sodium, arsenic, bicarbonate and sulphate exceeded the WHO limits in the tube well water. Hazard quotient of arsenic and cadmium was greater than 1 in tube well water. Study concluded that daily intake of heavy metal rich water caused potential health hazards among the local residents of study area. Irrigational suitability of tube well water was also analysed in terms of residual sodium carbonate, SAR, kelly's index, Na% and magnesium absorption ratio. Tube well water of both the areas was found unfit for irrigation in terms of sodium percent and kelly's index.

Shinzato & Hypolito, (2016) investigated the effect of disposal of aluminium recycling waste in soil and water bodies. The major waste products were dross, non-metal waste and liquid effluent. The disposal of dross (aluminium nitride) in soil decreased the pH (< 4) of groundwater and increased the aluminium, sodium, potassium, barium, nickel, lead, copper and zinc ion concentration. The disposal of untreated aluminium recycling wastes can contaminate groundwater and surface waters, majorly due to high level of N-NH_3 and is very toxic.

Chatterjee et al., (2017) studied the high arsenic problem in groundwater in West Bengal (India). In India and Bangladesh, arsenic contamination was a major problem of groundwater. They studied ground water chemistry and quality by a systematic screening operation of tube wells in West Bengal. Groundwater was mainly calcium bicarbonate type and at shallow depth it was sodium chloride type. The results of study revealed that the distribution pattern of metal in groundwater system was related with land-use characteristics. They also suggested that arsenic release was also affected by local land use conditions (municipal wastes and agricultural wastes).

Rezaei & Hassani, (2017) studied the groundwater hydrochemical parameters in the north of Isfahan, Iran. The results of the study were equated with the drinking guideline values of the world health organization (WHO). Analytical results concluded that groundwater of study area was alkaline in nature (from 7.05 to 8.95 with a mean of 7.78). TDS of 14% of the groundwater samples were higher than the standard limit of WHO. Electrical conductivity of 23% of the samples were more than the standard limit. The groundwater was majorly (45% of samples) sodium sulphate type.

Mattos et al., (2018) examined spatial-seasonal changes in quality of subsurface water in municipality of Lençóis (Bahia) in northeastern Brazil. They specified natural and anthropological factors that governed the hydrochemistry of water. From Gibbs plot, they concluded that rainfall recharge was more prevailed than rock-water interaction. Hydrolysis and mineral dissolution also controlled water chemistry of that area. At many clusters, waste water mobilization influenced groundwater chemistry in Lençóis. Similar type of seasonal and spatial variation in groundwater quality was studied by **Rouxel et al., 2011 (in France); Matini et al., 2012 (in Congo); Li et al., 2017 (in China); Kammoun et al., 2018 (in Tunisia); Edet, 2018 (in Nigeria); Chitsazan et al., 2019 (in Iran).**

Hausladen et al., (2018) examined the distribution pattern and sources of hexavalent chromium in groundwater of California. They identified the source of groundwater chromium from the metal plating industry around Los Angles and the San Francisco Bay areas, natural redox conditions along flow paths in the Mojave Desert and farming in the Central Valley of California.

Bexfield et al., (2019) detected the occurrence of hormone and pharmaceuticals in groundwater across the United States. They analysed the groundwater samples for 21 hormones and 103 pharmaceuticals. Thirty-four compounds were detected in analysed samples - one plastics component (bisphenol A), three pharmaceuticals (carbamazepine, sulfamethoxazole, and meprobamate), and the caffeine degradate 1,7-dimethylxanthine. At one site, hydrocortisone had a concentration greater than a human-health benchmark.

For the assessment of characteristics of groundwater, entropy-weighted water quality index method was used by many researchers **(He & Wu, 2019; Li et al., 2019; Su et al., 2019).** They concluded non-carcinogenic health risks in humans due to ingestion of nitrate, sulphate and chromium contaminated water. Irrigational suitability of groundwater of Guanzhong basin of China was studied by **Xu et al., (2019).** They reported that there was no alkali hazard due to use of groundwater for irrigation but soil can suffer slightly salinity hazard in that area. They suggested that salinity of soil could be controlled with proper drainage.

2.3 REVIEW OF NATIONAL STATUS OF GROUNDWATER QUALITY

Batheja et al., (2007) studied quality parameters of subsurface water at Churu tehsil of Rajasthan. Collected samples were analysed for TDS, EC and major ions (calcium, magnesium, nitrate, fluoride, sodium and potassium). On equating the analytical results with standards of Indian Council of Medical Research, they concluded that majority of samples were unfit for direct human consumption (having TDS > 1500 mg/L).

Muhamed & Mukundan, (2007) studied seasonal effects on drinking quality of groundwater at four stations (Kanakkankadavu, Purappallikavu, Pathalam and Manjummal) in the Periyar river basins in Ernakulam district of Kerala. Analytical data showed that calcium, magnesium, nitrate and sulphate content of groundwater were high in summer season and in monsoon season, water was acidic, turbid and less saline. During summer season, toxic metals were detected in samples of Kanakkankadavu and Purappallikavu. In samples of Kanakkandavu, mercury and lead were detected. Analytical results concluded that groundwater of that area was partially fit for human consumption and could be used after proper treatment.

Kumar et al., (2007) have investigated the suitability of groundwater for drinking and irrigation activities in two districts of Punjab - Patiala and Muktsar. Seasonal variation in groundwater quality was also investigated. By comparing the results with WHO standards, it was concluded that groundwater quality of district Patiala was better than that of Muktsar district. The effect of precipitation on groundwater of two district was different. Groundwater of Patiala district showed dilution while groundwater of Muktsar district showed more leaching of harmful chemicals during monsoon season.

Bangar et al., (2008) have studied irrigation suitability of groundwater in Ujjain district of Madhya Pradesh. Physico-chemical parameters were analysed in collected subsurface water samples. Out of 712 samples, 105, 144, 150, 84, 68, 111 and 50 samples belong to Ujjain, Mahidpur, Khachrod, Tarana, Barnagar, Nagda and ghatia tehsils of the district respectively. Analytical results were compared with standards of Central Soil Salinity Research Institute. Majority of samples (80%) showed good water quality, 14% of samples were saline and 6% of samples were alkaline. Dominant cations were Ca, Na and Mg and dominant anion was Cl followed by HCO_3

and CO_3. High negative correlation was observed between pH and SO_4 while Na with EC and HCO_3 with RSC showed significant positive correlation.

Gowd & Govil, (2008) studied the contamination of surface water bodies of Ranipet industrial area of Vellore district, on Chennai-Bangalore highway. A large number of industries, including 240 tanneries, were located in Ranipet town. The effluent of these industries were discharged into Puliathengal, Vanapadi and Thandalam lakes. The conclusion of the study was that surface water body of that area was contaminated with Cr, Cd, Cu, Pb, Ni and Zn. The ranges of analysed metals were - cadmium from 0.2 to 401.4 µg/L, chromium from 2.4 to 1,308.6 µg/L, copper from 2.1 to 535.5 µg/L, nickel from 1.6 to 147.0 µg/L, lead from 6.4 to 2,034.4 µg/L and zinc from 20.8 to 12,718.0 µg/L. High chromium content in water bodies was due to effluent coming from tanneries. Results of the investigation also concluded that residents of that area were suffering from many diseases like asthma, chromium ulcers and skin diseases.

Srivastava & Ramanathan, (2008) studied level of contamination in groundwater near Bhalswa landfill site by applying multivariate statistical techniques. High amount of nitrate, fluoride and heavy metal were present in groundwater. Leaching of hazardous metals from dumping sites to ground aquifer was evidenced by statistical analysis, temporal and spatial variation. The study revealed that hazardous chemicals were leaching from landfill site and affecting groundwater quality in nearby areas

Balakrishnan et al., (2008) studied the effect of effluents of dyeing industries on ground aquifers in Kancheepuram town of Chennai. The analytical results were as follows; TDS (1138 - 2574 mg/L), TH (225 - 760 mg/L), Cl (216 - 847 mg/L), SO_4 (64 - 536 mg/L), NO_3 (up to 58 mg/L), Fe (up to 2.3 mg/L) and Pb (up to 0.281 mg/L). The user specific water quality indices (USWQI) were also calculated for every collected sample. The USWQI for drinking suitability ranged from 85 to 30 showing fair type of water quality. The USWQI for agricultural suitability ranged from 89 to 50 showing good type of water quality. To provide safe drinking water to everyone, a comprehensive plan of action was recommended by the author in the studied region.

Garg et al., (2009) studied the drinking suitability of groundwater in Bhiwani region of western Haryana. After analyzing various quality parameters in collected 275 samples of groundwater, it was concluded that fluoride was major contaminant of groundwater. A maximum concentration of fluoride (86 mg/L) was obtained from Motipura village. Block wise percentage of samples with fluoride content above permissible limit of BIS - Siwani (84%) > Charki Dadri (58%) > Bhiwani (52%) > Bawani Khera (33%) > Loharu (14%). Author suggested that consumption of fluoride rich water can cause dental fluorosis among the residents of that area.

Evaluation of groundwater quality in various zones of Tamilnadu was done by various researchers **(Arumugam & Elangovan, 2009 (in Tirupur region, district Coimbatore); Kumar et al., 2009 (in Manimuktha river basin); Subramani et al., 2009 (in Chithar river basin); Balachandar et al., 2010 (in Coimbatore region); Nagarajan et al., 2010 (in Thanjavur city); Vasanthavigar et al., 2010 (in Thirumanimuttar sub-basin).** They all concluded the presence of excess of ions (potassium, nitrate, phosphate etc.) in groundwater.

Jain et al., (2010) evaluated the drinking quality of groundwater and spring water of Nainital district in Uttarakhand. Forty groundwater samples were examined for chemical, microbial and heavy metals characteristics. Seasonal variation in groundwater quality was also assessed during study period. Alkalinity of groundwater decreased in post-monsoon season (from a maximum value of 380 mg/L to 354 mg/L). Nearly 10% of analysed groundwater samples showed high TDS value indicating mineralization of groundwater. In 60% of samples nickel content was beyond the WHO standard (0.07 mg/L). All the analysed metal were within the prescribed limit. Only one sample showed high quantity of iron and Lead. Groundwater was free from any bacterial contamination but removal of microbial contamination in spring water was required. Similar type of studies were done by **Chatterjee et al., 2010** in Dhanbad district of Jharkhand. Dhanbad district is a major coal mining area of India. Despite of mining activities, drinking quality of groundwater of that area was good to excellent type.

Vyas, (2011) studied the water quality in Gandhinagar town of Gujarat. Gandhinagar town was the cultural, administrative and educational headquarter of Gujarat. It is a riverside city with a ribbon pattern. For the analysis of groundwater, 84 samples of tap water were collected from water system of the town during the period April 2006 to March 2007. All the collected samples were analysed for water quality parameters.

Analysed data was compared with BIS and WHO standards. From the results, it was observed that all analysed parameters were well below from the corresponding standard permissible limit. Low fluoride content (mean 0.6 mg/L) was analysed in 100% of samples. Nearly 13% of samples showed high iron content (mean 0.45 mg/L). The groundwater of study area was very hard. Major cations were Ca & Mg and major anions were CO_3 & HCO_3.

Vijay et al., (2011) examined the drinking suitability of subsurface water of Puri city in India. Study was carried out in post-monsoon season of year 2006 and summer season of year 2007. Drinking water standards of BIS and EPA were used to compare the analytical results. Seasonal variation was observed in water-quality parameters. Water quality in water fields was partially fit for human consumption. However in city, quality of water was adversely affected due to municipal wastes. The study concluded that groundwater was contaminated due to various domestic activities.

Kaur & Singh, (2011) have carried out studies on irrigation quality of groundwater in Bikaner city of Rajasthan. Major cations and anions were analysed in collected samples. To understand the irrigation suitability of water, chemical indices like SAR, percent sodium and RSC were measured on the basis of analytical results. Finally it was reported that some of the sampling sites were not fit for human consumption and irrigation activities.

Kamaldeep et al., **(2011)** identified the groundwater contamination due to industrial effluent in Baddi-Barotiwala industrial belt of district Solan in Himachal Pradesh. Effluent coming from various industrial establishments have deteriorated the quality of groundwater. Analytical results have been compared with the drinking standards of BIS. High content of metals like iron, copper, lead and manganese has been obtained from groundwater samples. Discharge of untreated industrial effluents was the major source of groundwater pollution in Baddi-Barotiwala area.

Singh et al., (2011) evaluated the groundwater quality in Shiwaliks of Punjab. Groundwater is the major source for irrigation of crops in Shiwaliks of Punjab. Principal components analysis (PCA) and other factor analysis were applied to interpret the analytical data. The PCA suggested that both anthropogenic and natural factors were responsible for excessive ion concentration in groundwater system. The content of manganese and cadmium were above the permissible limit at all sampling locations while lead and iron were higher than permissible limit at few locations. From piper graphical method, major hydrochemical facies of groundwater samples was Ca–Mg–HCO_3 type.

Mandal & Kumar, (2012) studied the groundwater contamination of Naraina industrial area of Delhi. Each sample was analysed for 13 physico-chemical parameters and 5 trace metals - Fe, Cu, Pb, Cr and Cd. All of the groundwater samples (except one) showed high value of TDS and trace elements. The mean concentration of metals were - Fe (0.04 ± 0.03 mg/L), Cu (0.04 ± 0.02 mg/L), Pb (0.03 ± 0.03 mg/L), Cr (0.04 ± 0.03 mg/L) and Cd (0.04 ± 0.02 mg/L). All the groundwater samples (except one) were in poor type of category of water. To identify the source of contamination, they recommended periodical assessment of groundwater quality. Characterization of industrial waste water was also suggested.

Vaishnav & Dewangan, (2012) studied the surface and sub- surface water of BALCO industrial area of Korba. The study period was from July 2009 to Dec 2009. Four groundwater samples and six samples of surface water were analysed for quality parameters & metals (Fe, Al, Mn, As and Zn). Interpretation of analytical data was done through statistical parameters- mean, standard error, % CV (coefficient of variation), correlation coefficient and WQI. The water samples collected from both ground and surface sources showed high concentration of ions and metals. At few places, metal concentration was much higher than prescribed limit.

Singh & Ghosh, (2012) analysed arsenic concentration in groundwater of two panchayat of Patna district of Bihar- Rampur Diara (RD) and Haldichapra (HC). Risk assessment due to intake of arsenic rich water was also done. All the analysed samples crossed the standard limit of WHO and BIS. For health risk assessment, population of 264 from panchayat RD and 222 from panchayat HC were taken into study. Four age groups of population were chosen for health assessment - children (5–10 years), youth (11–20 years), adults (21–39 years), and the elderly (40+ years). Hazard quotients were also calculated for both district. It was from 12.1 to 41.6 (RD population) and from 58.3 to 192.5 (HC population). Analytical results revealed that children of HC population were more prone to cancer than those of RD population.

Ananthakrishnan et al., (2012) investigated the subsurface water quality in Alathur block of Perambalur district for drinking suitability. The study was conducted over ten villages in Perambalur district of Tamilnadu. It covers more than 60 sq.km. Ten bore wells in the fertile area were selected for their study. Physico-chemical parameters of bore well water were analysed three times in a year (pre-monsoon, monsoon and post- monsoon). From the results, it was revealed that most of the parameters in all three seasons exceeded the desirable limit given by WHO and ICMR standards.

Das et al., (2013) examined major ions, heavy metals and microbial content of water samples from chromite mine quarry of Sukinda and nearby areas. Mine water possessed high concentrations of heavy metals (chromium > iron > zinc > nickel > cobalt > manganese). Ground water samples were free from metal contamination. Only few samples showed presence of iron in it. Quality of mine water was different from nearby areas. Microbial population of mine water was lesser than water of areas near to mine. Bacterial colony obtained from mine water showed more resistence towards chromium, other heavy metals and antibiotics. It was an indication of heavy metal contamination of groundwater.

Kanmani & Gandhimathi, (2013) investigated the impacts of leachate originated from an open dumping site in Ariyamangalam of Tiruchirappalli district in Tamil Nadu, on groundwater. Groundwater samples were examined for various physico-chemical parameters and five metals (Cd, Cu, Mn, Pb, and Zn). Analytical results showed saline nature (TDS 740 – 14,200 mg/L) of groundwater. Groundwater pH, sulphates and nitrates concentration were well below the prescribed limit of BIS and WHO. Chloride concentration ranged from 215.15 to 4,098.73 mg/L. High lead content (0.59 mg/L) was obtained from groundwater samples collected near to dumping site. Results of study concluded that groundwater of Ariyamangalam site was polluted from the chemicals present in leachate.

Dubey et al., (2014) assessed the quality of groundwater of Dwarka district of Delhi. Study was carried out in June 2013. Various quality parameters were analysed in Dwarka sub-city and Najafgarh drain samples. Analytical results were expressed in terms of WQI. Measured WQI ranged from 58.3 (Dwarka Sec. 6) to 907.2 (Dwarka Sec. 12). According to value of WQI, 30.77% of samples were not fit for human consumption, 46.15% of samples showed poor quality of water and 19.23% of samples have been categorised into poor quality.

Impacts of disposal of solid wastes on ground water quality was studied by **Nandwana & Chhipa, (2014)** at different disposal site at Jaipur. The results of study concluded that the waste water which was generated due to biodegradation of waste percolated down to soil layers and caused contamination of ground water.

Manjeet et al., (2014) have studied the potability of groundwater in various villages of Gurgaon district of Haryana. The fluoride level in groundwater was also assessed during study. Nearly 24% of analysed samples were having fluoride concentration above the standard limit. Authors concluded both natural and anthropogenic sources of fluoride in groundwater. Dissolution of fluoride rich minerals like apatite, fluorite and mica was responsible for fluoride rich groundwater in that area. Effluents of various industries were also contributed for high fluoride content.

Karthika et al., (2015) analysed the effluent coming from paper and pulp industry and its impact on ground water quality at Madathukulam, Udumalpet city. The TDS of effluent of paper industry was 1329 mg/L while TDS of groundwater was four times higher than the standard value of BIS.

Basavarajappa & Manjunatha, (2015) analysed the quality of groundwater in Precambrian rocks of Chitradurga district of Karnataka, using geo-informatics techniques.

Selvam et al., (2016) identified the sources of groundwater pollution in Dindigal district of Tamil Nadu. The study area was having 80 functional tanneries. The effluent of tanneries was deteriorating groundwater quality. Contamination of groundwater was also due to irrigation return flow, municipal waste water, and discharge of septic tanks.

Bhutiani et al., (2016) examined the groundwater quality of Haridwar. They analysed heavy metals (Cr, Co, Ni, Fe and Zn) in the collected samples. To analyse the data, principal component analysis & hierarchial cluster analysis were done. In nearly 94% of samples heavy metals were obtained. Maximum concentration of all the analysed metals (except Zn) exceeded the corresponding guideline value given by WHO & BIS. Iron was found in higher concentration in monsoon season due to increased rate of rusting of pipes and more dissolution of iron in rain water. The report concluded the absence of carcinogenic effect among the population of that area.

Gupta & Sharma, (2016) analysed the spatial variation in quality of groundwater with depth in Delhi region. Study period was from 2012 to 2014. From the data obtained from analysis, variability maps were plotted with kriging tool. The analytical results were in negative correlation with the depth of groundwater. The prepared distribution maps of various parameters showed that the physico-chemical values were higher in northern region while groundwater depth was maximum in southern part of study area.

Selvakumar et al., (2017) examined quality parameters of twenty groundwater samples of southern Tiruchirappalli district of Tamilnadu. The analytical results indicated alkaline nature of groundwater. The dominant cations were Na, Ca & Mg and dominant anions were HCO_3, Cl, SO_4 & NO_3. Hardness of majority of samples and TDS of 55% of samples were well below corresponding standard limit of WHO. According to the Piper plot, dominant hydrochemical facies were Ca–Mg–Cl, Ca–HCO_3, and Ca–Cl type.

Tirkey et al., (2017) compared the quality of groundwater in different zones of Ranchi city of Jharkhand. They analysed physico-chemical parameters and ten heavy metals in groundwater samples. Out of total analysed metals, As, Mn, Ni and Se varied from 0 to 200 µg/L, 0 to 80 µg/L, 0 to 4200 µg/L and 30 to 140 µg/L respectively. Results of principal component analysis and correlation study concluded that Ca, Na and HCO_3 were dominant ions. The decreasing order of relative concentration of the cations was $Ca_{\sim}Na$ > Mg > K and for anions was Cl > SO_4 > NO_3 > F > PO_4. Results of zonal variation revealed that industrial and commercial zones had poor water quality compared to rural, peri-urban and urban zones. Results of water quality index (WQI) values showed that only 9% of samples had good water quality. The results of study also concluded that risks of non-carcinogenic effect of arsenic and selenium were high among the residents of study area.

Jareda et al., (2018) analysed the subsurface water quality of Bailadila iron mines and nearby regions of Dantewada district in Chhattisgarh. Five metals (Al, Cr, Pb, Fe & Zn) were analysed in collected samples. Seasonal variation in metal concentration was also analysed. Analytical results revealed that metal concentration in groundwater of Bailadila iron ore mine area followed the trend Fe > Zn > Al > Cr > Pb. Overall results of study concluded that groundwater of mine area was contaminated and not safe for human consumption.

Adimalla et al., (2018) analysed fluoride and nitrate pollution in groundwater of Nirmal district of Telangana. This state has fluoride mineral rich granite rocks hence distribution of fluoride in ground aquifers is high **(Adimalla & Venkatayogi, 2017).** The results of study concluded that nearly 26% of samples crossed the standard limit of nitrate and nearly 21% of samples were beyond the permissible limit of fluoride set by BIS. Total health index values of groundwater samples showed that 67.65% (for men), 79.41%, (for women) and 82.35% (for children) of samples were above total health index.

Jampani et al., (2018) analysed the groundwater of Kachiwani Singaram of the Musi river basin adjacent to the city of Hyderabad. Kachiwani Singaram region was using waste water irrigation technique from last 40 years. The groundwater quality was negatively affected by this process. Groundwater became excessive saline due to waste water irrigation. They outlined total dissolved solids of groundwater in the range of 430 mg/L to 2221 mg/L and the sodium content of groundwater from 35 to 379 mg/L. They also concluded that ion content increased after precipitation. Similar type of results were obtained by **Negi et al., 2018** in groundwater of Chandigarh, Panchkula, and Mohali city of Punjab where shallow groundwater samples had ammonical nitrogen (9.8 mg/L), COD (128 mg/L), Cl (115 mg/L), Na (98 mg/L) and K (42.2 mg/L).

Gaikwad et al., (2019) studied mobility of ions in ground aquifers of Terakhol river basin in Sindhudurg district of coastal Maharashtra. They analysed sixty-five groundwater samples. Analytical results showed acidic to alkaline nature of water. pH, bicarbonate and fluoride content of groundwater samples were above the standard value of WHO. High fluoride level of water was due to rock-water interaction. The decreasing order of major ions was Ca > Na > Mg > K (cations) and HCO_3 > Cl> SO_4 > NO_3 > F (anions). Piper plot of ions showed that Ca-HCO_3 and Ca-Cl-HCO_3 were dominant hydrochemical facies of groundwater. Irrigation suitability of groundwater was also studied on the basis of USSL, SAR, Na% and kelly index. Salinity and sodicity of water were appropriate for crop irrigation however kelly index of 78.47% of samples was greater than 1.

Rao & Latha, (2019) studied chemistry of subsurface water in tribal region of Gosthani river basin, in Andhra Pradesh. Hydrochemistry of this region was mainly controlled by geology of area. To understand the drinking and irrigational quality of groundwater, various quality parameters were computed. Results showed lesser concentration of major ions in groundwater. However iron content was found high due to water-rock interchange. Due to insufficient amount of necessary minerals in water, residents of area suffered from various health problems.

Upadhyay et al., (2019) investigated the problem of arsenic contamination in remote areas of West Bengal. To identify the source of arsenic toxicity in human beings, they collected soil samples, groundwater samples and rice samples from two villages- Sarapur & Chinili. Results of arsenic analysis showed that arsenic concentration in groundwater exceeded drinking standards of BIS and WHO. The level of soil arsenic was also above from European Union maximum acceptable limit in agricultural soil (20 mg/Kg). Analysed arsenic level in rice grains was beyond the safe level given by FAO/WHO (0.2 mg/Kg). They concluded that children and toddlers were at high risks of arsenic exposure in study area.

2.4 REVIEW OF UTTAR PRADESH STATUS OF GROUNDWATER QUALITY

Groundwater quality of three villages (Lutfullapur, Nawada and Loni) of district Ghaziabad was analysed by **Singh et al., (2012).** Industrial effluents of dyeing industries were allowed to flow through a drain in Khekra area of Baghpat. A degradation in quality of groundwater due to drain was observed. They also analysed appropriateness of groundwater for drinking and irrigation. At most of the sampling sites, EC, TA, Cl, Ca, Na, K and Fe content of groundwater were above the prescribed limit of BIS. Piper trilinear diagram showed dominant hydrochemical facies was Na-K-Cl-SO_4, Na-K-HCO_3 and Ca-Mg-Cl-SO_4. Agricultural suitability of groundwater was assessed on the basis of salinity, chlorinity and sodicity. Results indicate that groundwater was suitable for irrigation. Industrial suitability of groundwater was analysed by Langelier Saturation Index and Ryznar Stability Index. Results of both the index value showed that most of samples were $CaCO_3$ depositing in nature.

Bisht et al., (2013) studied the quality of drinking water from four different locations (Lohia Nagar, Sec. 16, Jatwara & Sahibabad) in Ghaziabad. Analytical results revealed that fluoride concentration of all the samples was higher (1.66 to 4.68 mg/L) than standard limit of BIS. Jatwara sample showed high nitrate concentration (187.583 mg/L). Aluminium and Iron concentration of Sahibabad sample were higher, 228.88 ppb & 4598.76 ppb respectively. Rest of the quality parameters were well below the safe limit. They concluded that the water from the study area can be used for drinking after removal of excess of fluoride, nitrate, aluminium & iron.

Singh et al., (2014) examined the quality of groundwater in Ghaziabad (indo-gangetic plain) for drinking and irrigation purpose. They analysed various quality parameters and heavy metals in samples collected in both pre-monsoon and post-monsoon season. Results of study revealed that chemical composition of groundwater was affected by the waste water of agricultural, industrial, and domestic areas. Iron content of 41% and 70% of samples (pre and post-monsoon season respectively) was higher than the desirable limit of BIS. Chromium, copper, and lead content were also higher than their respective drinking desirable limits of BIS. It was recommended by the author that groundwater of Ghaziabad was appropriate for irrigation but not fit for human consumption.

Similar type of groundwater analysis was done by **Tiwari & Singh, (2014)** in Pratapgarh District.

Singh & Tripathi, (2016) carried out their study in Noida region in NCR of Delhi. They used factor analysis to explain the processes which affect the groundwater quality of that area. Thirty-three samples of groundwater were collected and 18 hydro-chemical parameters were examined. The three factor model (salinity, alkalinity and pollution) explained 79.30% of total variance. Factor 1 (47.25% of the total variance) showed strong positive loadings with Mg, Na, Cl, SO_4, EC, TDS and TH. Factor 2 (16.75 % of the total variance) explained moderate positive loadings with K, Ca, HCO_3, and CIA. While factor 3 (15.30 % of the total variance) showed strong positive loadings with Na% and SAR. Multivariate analysis revealed that the over-pumping and pollution caused negative effects on water quality. They also recommended rainwater harvesting and groundwater recharging techniques to save ground aquifers.

Kumar et al., (2016) studied impacts on environment due to disposal of livestock and domestic wastes in wetland in Lucknow, India. An extensive study was done in three season (summer, monsoon & winter) of year 2014. The results of study revealed that concentration of PO_4, SO_4, alkalinity, Cl, pH and TH were higher in summer season. However nitrate concentration in groundwater was higher in monsoon season (17.12 mg/L). All the analysed metals (except copper) were obtained in higher concentration in winter season.

Singh & Hussain, (2016) used water quality index method to assess the drinking quality of groundwater of Greater Noida city. A total of 47 samples of groundwater were tested for eleven parameters (pH, Ca, Mg, TDS, chloride, nitrate, sulphate, fluoride, bicarbonate, Na and K). The results were used to calculate the WQI. On the basis of WQI value, nearly 96% of water samples showed good water quality (WQI; 53.69 TO 267.85) except samples collected from CHI-3 & Radisson hotel. The groundwater samples of these two locations showed high value of EC, TDS, Na, Mg and Cl. The results indicated groundwater of Echar village was best for drinking purpose.

Chabukdhara et al., (2017) studied the groundwater quality of urban and peri- urban region of Ghaziabad district in Uttar Pradesh, India. They analysed all the physico-chemical parameters and heavy metals. The source of heavy metal in groundwater of district and the pollution level of metals were also analysed using multivariate analysis.

Saleem et al., (2017) studied the current threats related to groundwater quantity and quality in Greater Noida city of Uttar Pradesh. The major issues were excess groundwater extraction and reclamation activities. Aim of study was to develop a numerical model for groundwater flow and contaminant transport through visual modflow and effective groundwater management. The model was helpful to understand the behaviour of groundwater system, environmental challenges and to install suitable measures to check further contamination of ground aquifer. From the results obtained from analysis of groundwater flow modelling, it was concluded that model was most sensitive to hydraulic conductivity and recharge parameters.

Kumar et al., (2017) assessed health risks among the residents of Chhaprola Industrial Area of district Gautam Buddha Nagar of Uttar Pradesh, due to consumption of metal contaminated water. They also investigated spatial variation in ion concentration and metal concentration of groundwater in study area. Analytical results revealed that out of 28 analysed elements, concentration of some toxic metals - Al, As, B, Cd, Cr, Mn, Pb and U were more than their corresponding BIS & WHO standards. Hazard quotient for these elements was more than 1. Rest of the analysed elements were well below the standard value. They also analysed level of γ and β radiation and found it below the standard limit.

Idrees et al., (2018) studied the cadmium level of groundwater and its toxic effects in four district of west Uttar Pradesh. Cadmium is a toxic heavy metal used in Ni-Cd batteries. It can also enters the environment through the discoloration of various plastics and electronic products. Cadmium concentration in groundwater of four district was as - (Shahjehanpur (0.06 ± 0.01 mg/L), Bareilly (0.07 ± 0.01 mg/L), Moradabad (0.06 ± 0.01 mg/L) and Rampur (0.05 ± 0.01mg/L).

Kumar et al., (2019) tested trace metal contamination in groundwater of Saharanpur district. They also studied groundwater contamination level using contamination index and heavy metal pollution index. The concentration of As, B and Pb were found beyond the standard drinking water limits of WHO and BIS. Results of factor analysis (PCA and CA) showed that iron, manganese and lead concentration were linked with principal component analysis 1 and had both geogenic and anthropogenic sources. Boron and copper (PC2) were having anthropogenic source while arsenic (PC3) had natural origin. According to HPI values, groundwater was metal contaminated and can cause adverse health effects among the local residents of the area.

From the citation of literature as above it is evident that a lot of worldwide work on groundwater quality is available. Various attempts have been made by different scientists to investigate the suitability of groundwater for drinking and irrigation purposes. They also studied the source of contamination of groundwater. Many indexing methods and statistical approach have been adopted by researchers. However only a meager work is conducted in current study area on the impacts of effluents on groundwater chemistry. Therefore the present investigation was carried out.

REFERENCES

1. Abdalla F., Khalil R., 2018. Potential effects of groundwater and surface water contamination in an urban area, Qus City, Upper Egypt. Journal of African Earth Sciences. 141, 164-178.
2. Aderemi O.A., Oriaku V.A., Adewumi A.G., Otitoloju A.A., 2011. Assessment of groundwater contamination by leachate near a municipal solid waste landfill, African Journal of Environmental Science and Technology 5, (11) 933-940.
3. Adhikary P.P., Chandrasekharan H., Chakraborty D., Kamble K., 2010. Assessment of groundwater pollution in West Delhi, India using geostatistical approach, Environmental Monitoring & Assessment, 167, (1) 599-615.
4. Adimalla N., Li P., Qian H., 2018. Evaluation of groundwater contamination for fluoride and nitrate in semi-arid region of Nirmal Province, South India: A special emphasis on human health risk assessment (HHRA). Human and Ecological Risk Assessment: An International Journal. DOI: 10.1080/10807039.2018.1460579
5. Adimalla N., Venkatayogi S., 2017. Mechanism of fluoride enrichment in groundwater of hard rock aquifers in Medak, Telangana State, South India. Environmental Earth Sciences. 76, (45). doi:10.1007/s12665-0166362-2
6. Aghazadeh N., Mogaddam A.A., 2010. Assessment of Groundwater Quality and its Suitability for Drinking and Agricultural Uses in the Oshnavieh Area, Northwest of Iran. Journal of Environmental Protection. 1, 30-40.
7. Akinbile O.C., Yusoff S.M., 2011. Environmental Impact of Leachate Pollution on Groundwater Supplies in Akure, Nigeria. International Journal of Environmental Science and Development, 2, (1) 81-86.

8. Aly A.A., Al-Omran A.M., Alharby M.M., 2014. The water quality index and hydrochemical characterization of groundwater resources in Hafar Albatin, Saudi Arabia. Arabian Journal of Geosciences, 8, (6) 4177–4190.
9. Ananthakrishnan, Locanadhan K., Zafarahamed A., 2012. Groundwater Quality in Alathur block-Perambalue District for drinking suitability. Scholars Research Library, Activities of Applied Sciences Research. 4 (3).
10. Annual Report 2014-2015, 2015, Central Ground Water Board.

11. Arumugam K., Elangovan K., 2009. Hydrochemical characteristics and groundwater quality assessment in Tirupur Region, Coimbatore District, Tamil Nadu, India. Environmental Geology. 58, 1509–1520.
12. Asadi P., Ashtiani B.A., Beheshti A., 2017. Vulnerability assessment of urban groundwater resources to nitrate: the case study of Mashhad, Iran. Environmental Earth Sciences. 76, (41).
13. Azom M.R., Mahmud K., Yahya S.M., Sontu A., Himon S.B., 2012. Environmental Impact Assessment of Tanneries: A Case Study of Hazaribag in Bangladesh. International Journal of Environmental Science and Development. 3, (2) 152-156.
14. Balachandar D., Sundararaj P., Rutharvel Murthy K., Kumaraswamy K., 2010. An Investigation of Groundwater Quality and Its suitability to Irrigated Agriculture in Coimbatore District, TamilNadu, India – A GIS Approach. International Journal of Environmental Sciences. 1, (2) 176-190.
15. Balakrishnan M., Antony S.A., Gunasekaran S., Natarajan R.K., 2008. Impact of dyeing industrial effluents on the groundwater quality in Kancheepuram (India). Indian Journal of Science and Technology. 1, (7).
16. Bangar K.S, Tiwari S.C., Varma S.K., Khandkar U.R., 2008. Quality of Groundwater used for Irrigation in Ujjain District of Madhya Pradesh, India. Journal of Environmental Sciences and Engineering. 50, 179-186.
17. Basavarajappa H.T., Manjunatha M.C., 2015. Groundwater Quality Analysis in Precambrian Rocks of Chitradurga District, Karnataka, India using Geo-informatics Technique. Aquatic Procedia. 4, 1354-1365.
18. Batheja K., Sinha A.K., Seth G, Garg J., 2007. Physico-Chemical characterstics of groundwater at Churu Tehsil, Rajasthan, India. Journal of Environmental Sciences and Engineering. 49, (3) 203-206.
19. Bexfield L.M., Toccalino P.L., Belitz K., Foreman W.T., Furlong E.T., 2019. Hormones and Pharmaceuticals in Groundwater Used As a Source of Drinking Water Across the United States. Environmental Science & Technology. 53, 2950−2960.
20. Bhattacharya S., Guha G., Chattopadhyay D., Mukhopadhyay A., Dasgupta K.P., Sengupta K.M., Ghosh C.U., 2013. Codeposition and Distribution of Arsenic and Oxidizable Organic Carbon in the sedimentary basin of W. Bengal, India. Journal of Analytical Science and Technology. 4, (11).

21. Bhutiani R., Kulkarni D.B., Khanna D.R., 2016. Water Quality, Pollution Source Apportionment and Health Risk Assessment of Heavy Metals in Groundwater of an Industrial Area in North India, Expo Health, Springer Science. (8), 3–18.
22. Bisht S., Patra B.A., Malik M., 2013. Drinking water assessment of 4 locations from Ghaziabad, Uttar Pradesh. Current world Environment. 8, (1) 103-106.
23. Bougherira N., Hania A., Djabria L., Toumia F., Chaffaia H., Haiedb N., Nechema D., Sedratia N., 2014. Impact of the urban and industrial waste water on surface and groundwater, in the region of Annaba, (Algeria). Energy Procedia. 50, 692 – 701.
24. Cai L.M., Xu Z.C., Qi J.Y., Feng Z.Z., Xiang T.S, 2015. Assessment of exposure to heavy metals and health risks among residents near Tonglushan mine in Hubei, China. Chemosphere. 127, 127-135.
25. CGWB (2010) Ground water quality in shallow aquifers of India. Central Ground Water Board, Ministry of Water Resources, Government of India, Faridabad.
26. Chabukdhara M., Gupta S.K., Kotecha Y., Nema A.K., 2017. Groundwater quality in Ghaziabad district, Uttar Pradesh, India: Multivariate and health risk assessment. Chemosphere. 179, 167-178.
27. Chatterjee D., Kundu A., Saha D., Barmana S., Mandal U., 2017. Groundwater Arsenic in the Bengal Delta Plain: Geochemical and Geomorphological Perspectives. Procedia Earth and Planetary Science. 17, 622 – 625.
28. Chatterjee R., Tarafder G., Paul, S., 2010. Groundwater quality assessment of Dhanbad district, Jharkhand, India. Bulletin of Engineering Geology and the Environment. 69, 137–141.
29. Chitsazan M., Aghazadeh N., Mirzaee Y., Golestan Y., 2019. Hydrochemical characteristics and the impact of anthropogenic activity on groundwater quality in suburban area of Urmia city, Iran. Environment Development and Sustainability. 21, (1) 331-351.
30. Das S., Patnaik S.C., Sahu H.K., Chakraborty A., Sudarshan M., Thatoi H.N., 2013. Heavy metal contamination, physico-chemical and microbial evaluation of water samples collected from chromite mine environment of Sukinda, India. Transactions of Nonferrous Metals Society of China. 23, 484−493.
31. Dubey R.K., Hussain J., Malhotra N., Mehta A., 2014. Ground Water Quality and Water Quality Index of Dwarka District of National Capital of India. International Journal of Research in Engineering and Technology. 3, (4) 85-93.

32. Edet A., 2018. Seasonal and spatio-temporal patterns, evolution and quality of groundwater in Cross River State, Nigeria: implications for groundwater management. Sustainable Water Resources Management. 5, (2) 667–687.
33. Ezekwe I.C., Odu N.N., Chima G.N., Opigo A., 2012. Assessing regional groundwater quality and its health implications in the Lokpaukwu, Lekwesi and Ishiagu mining areas of southeastern Nigeria using factor analysis. Environmental Earth Sciences. 67, 971–986.
34. Gaikwad S., Gaikwad S., Meshram D., Wagh V., Kandekar A., Kadam A., 2019. Geochemical mobility of ions in groundwater from the tropical western coast of Maharashtra, India: implication to groundwater quality. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-019-00312-9.
35. Garg V.K., Suthar S., Singh S., Sheoran A., Garima, Meenakshi, Jain S., 2009. Drinking water quality in villages of southwestern Haryana, India: assessing human health risks associated with hydrochemistry. Environmental Geology. 58, 1329–1340.
36. Gowd S.S., Govil P.K., 2008. Distribution of heavy metals in surface water of Ranipet industrial area in Tamil Nadu, India. Environmental Monitoring & Assessment. 136, 197–207.
37. Gupta P., Sharma K., 2016. Spatial distribution of various parameters in groundwater of Delhi, India, Cogent Engineering.
38. Hakim M.A., Juraimi A.S., Begum M., Hasanuzzaman M., Uddin M.K., Islam M.M., 2009. Suitability Evaluation of Groundwater for Irrigation, drinking and Industrial Purposes in chiribandar in Dinajpur District of Bangladesh. American Journal of Environmental Sciences. 5, (3) 413-419.
39. Hausladen D.M., Alexander-Ozinskas A., McClain C., Fendorf S., 2018. Hexavalent Chromium Sources and Distribution in California Groundwater. Environmental Science & Technology. 52, (15) 8242-8251.
40. He S., Wu J., 2019. Relationships of groundwater quality and associated health risks with land use/land cover patterns: A case study in a loess area, Northwest China. Human and Ecological Risk Assessment: An International Journal. 25, (1-2) 354-373.
41. Idrees N., Tabassum B. Abd_Allah E.F., Hashem A., Sarah R., Hashim M., 2018. Groundwater contamination with cadmium concentrations in some West U.P. Regions, India. Saudi Journal of Biological Sciences. 25, 1365–1368.

42. Jain C.K., Bandyopadhyay A., Bhadra A., 2010. Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. Environmental Monitoring & Assessment, 166, 663–676.
43. Jampani M., Huelsmann S., Liedl R., Sonkamble S., Ahmed S., Amerasinghe P., 2018. Spatio-temporal distribution and chemical characterization of groundwater quality of a wastewater irrigated system: A case study. Science of the Total Environment. 636, 1089-1098.
44. Jareda G., Mahapatra S.P., Dhekne P.Y., 2018. Water quality index, heavy metal pollution index and seasonal variation correlation of groundwater of Bailadila iron ore mine area and its peripherals: Dantewada district, Chhattisgarh, India. Desalination and Water Treatment. 101, 7–16.
45. Jesmanitafti N., Jozi S.A., Monavari S.A., 2014. Review the Environmental Effects of Using Industrial Wastewater Effluent (Case Study: Iran Qom Shokouhie Industrial State). Journal of Environmental Protection. 5, 874-885.
46. Jiang Y., Wu, Y., Groves, C., Yuan, D., Kambesis P., 2009. Natural and anthropogenic factors affecting the groundwater quality in the Nandong karst underground river system in Yunan, China. Journal of Contaminant Hydrology. 109, 49-61.
47. Kamaldeep, Rishi M.S., Kochhar N., Ghosh N., 2011. Impact of industrialization on groundwater quality - A case study of baddi-barotiwala industrial belt, Distt. Solan, Himachal Pradesh, India. Journal of Industrial Pollution Control. 27, (2) 153-159.
48. Kammoun S., Re V., Trabelsi R., Zouari K., Daniele S., 2018. Assessing seasonal variations and aquifer vulnerability in coastal aquifers of semi-arid regions using a multi-tracer isotopic approach: the case of Grombalia (Tunisia). Hydrogeology Journal. 26, (8) 2575–2594.
49. Kanagaraj G., Elango L., 2019. Chromium and fluoride contamination in groundwater around leather tanning industries in southern India: Implications from stable isotopic ratio δ^{53}Cr/ δ^{52}Cr, geochemical and geostatistical modelling. Chemosphere. 220, 943-953.
50. Kanmani S., Gandhimathi R., 2013. Investigation of physicochemical characteristics and heavy metal distribution profile in groundwater system around the open dump site. Applied Water Science. 3, 387–399.

51. Karthika I.N., Jesu A., Dheenadayalan M.S., 2015. The Physico –Chemical Analysis of Paper Industry Effluent and its Impact of Ground Water Quality at Madathukulam, Udumalpet City. International Journal of Pharm Tech Research. 8, (6) 12-18.
52. Kaur R., Singh R.V., 2011. Groundwater Quality in Bikaner city, Rajasthan for Irrigation purpose, Applied Sciences in Environmental Sanitation. 6, 388-392.
53. Kumar A., Kumar V., Dhiman N., Ojha A., Bisen P., Singh A., Markandeya, 2016. Consequences of environmental characteristic from livestock and domestic wastes in wetland disposal on ground water quality in Lucknow (India), International Research Journal of Public Environmental Health. 3, (6) 112-119.
54. Kumar M., Kumari K., Ramanathan A.L., Saxena R., 2007. A comparative evaluation of groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab, India, Environmental Geology. 53, 553–574.
55. Kumar M., Nagdev R., Tripathi R., Singh V.B., Ranjan P., Soheb M., Ramanathan A.L., 2019. Geospatial and multivariate analysis of trace metals in tubewell water using for drinking purpose in the upper Gangetic basin, India: Heavy metal pollution index. Groundwater for Sustainable Development. 8, 122-133.
56. Kumar M., Ramanathan A.L., Tripathi R., Farswan S., Kumar D., Bhattacharya P., 2017. A study of trace element contamination using multivariate statistical techniques and health risk assessment in groundwater of Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India. Chemosphere. 166, 135–145.
57. Kumar P.J.S., 2014. Evolution of groundwater chemistry in and around Vaniyambadi Industrial Area: Differentiating the natural and anthropogenic sources of contamination. Geochemistry. 74, (4) 641-651.
58. Kumar S.K., Rammohan V., Sahayam J.D., Jeevanandam M., 2009. Assessment of groundwater quality and hydrogeochemistry of Manimuktha River basin, Tamil Nadu, India. Environmental Monitoring and Assessment. 159, 341–351.
59. Lerner D.N., Harris B., 2009. The relationship between land use and groundwater resources and quality. Land Use Policy. 26S, S265-S273.
60. Li P., He X., Guo W., 2019. Spatial groundwater quality and potential health risks due to nitrate ingestion through drinking water: A case study in Yan'an City on

the Loess Plateau of northwest China. Human and Ecological Risk Assessment. https://doi.org/10.1080/10807039.2018.1553612

61. Li P., He S., He X., Tian R., 2017. Seasonal Hydrochemical Characterization and Groundwater Quality Delineation Based on Matter Element Extension Analysis in a Paper Wastewater Irrigation Area, Northwest China. Exposure and Health. 10, (4) 241–258.
62. Liu G., Yu Y., Hou J., Xue W., Liu X., Wang W., Alsaedi A., Hyat T., Liu Z., 2014. An ecological risk assessment of heavy metal pollution of the agricultural ecosystem near a lead-acid battery factory. Ecological Indicators. 47, 210-218.
63. Mandal P., Kumar S., 2012. Assessment of Groundwater Quality in Industrial Areas of Delhi, India by Indexing Method. Water Quality Monitoring and Assessment.
64. Manjeet, Singh B.P., Sharma J.K., 2014. Assessment of Quality of Ground Water in Some Villages of Gurgaon District, Haryana (India): Focus on Fluoride. International Journal of Innovative Research in Science, Engineering and Technology. 3, (4) 11441-11448.
65. Matini L., Tathy C., Moutou J.M., 2012. Seasonal Groundwater Quality Variation in Brazzaville, Congo. Research Journal of Chemical Sciences. 2, (1) 7-14.
66. Matta G., Kumar A., Walia A., Kumar S., Mishra H.K., Dhingra G.K., Pokhriyal P., Wats M., 2016. Quality estimation of Ground water in Industrial estate of Uttarakhand. Pollution Research. 35, (4) 849-854.
67. Mattos J.B., Cruz M.J.M., De Paula F.C.F., Sales E.F., 2018. Natural and anthropic processes controlling groundwater hydrogeochemistry in a tourist destination in northeastern Brazil. Environmental Monitoring and Assessment. 190, 395.
68. Meenakshi, Garg V.K., Kavita, Renuka, Malik A., 2004. Groundwater quality in some villages of Haryana, India: focus on fluoride and fluorosis. Journal of Hazardous Material. 106, (1) 85-97.

69. Muhamed A.P., Mukundan M.K., 2007. Seasonal Variations in Water Quality of Four Stations in the Periyar River Basin. Journal of Environmental Sciences and Engineering. 49, (2) 127-132.

70. Nagamani C., Saraswathi Devi C., Shalini A., 2015. Physico-chemical analysis of water samples. International Journal of Scientific & Engineering Research. 6, (1) 2149-2155.

71. Nagarajan R., Rajmohan N., Mahendran U., Senthamilkumar S., 2010. Evaluation of groundwater quality and its suitability for drinking and agricultural use in Thanjavur city, Tamil Nadu, India. Environmental Monitoring and Assessment. 171, (1-4) 289-308.

72. Nandwana R., Chhipa R.C., 2014. Impact of Solid Waste Disposal on Ground Water Quality in Different Disposal Site at Jaipur, India. International Journal of Engineering Sciences & Research Technology. 3, (8) 93-101.

73. Negi P., Mor S., Ravindra K., 2018. Impact of landfill leachate on the groundwater quality in three cities of North India and health risk assessment. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-018-0257-1

74. Ngah W.S.W., Teong L.C., Toh R.H. and Hanafiah M.A.K.M., 2012. Utilization of chitosan–zeolite composite in the removal of Cu (II) from aqueous solution: Adsorption, desorption and fixed bed column studies. Chemical Engineering Journal. 209, 46–53.

75. Nowak B., Rocha S.F., Aschenbrenner P., Rechberger H., Winter F., 2012. Heavy metal removal from MSW fly ash by means of chlorination and thermal treatment: Influence of the chloride type. Chemical Engineering Journal. 179, 178-185.

76. Olaoye R.A., Oladeji O.S., 2015. Preliminary Assessment of Effects of Paint Industry Effluents on Local Groundwater Regime in Ibadan, Nigeria. International Journal of Engineering Research. 4, (10) 518-522.

77. Pourghasemi H.R., Beheshtirad M., 2015. Assessment of a data-driven evidential belief function model and GIS for groundwater potential mapping in the Koohrang Watershed, Iran. Geocarto International. 30, (6) 662-685.

78. Rahmati O., Samani A.N., Mahmoodi N., Mahdavi M., 2015. Assessment of the contribution of N-fertilizers to nitrate pollution of groundwater in Western Iran (Case Study: Ghorveh-Dehgelan Aquifer). Water Quality Exposure and Health. 7, 143–151.

79. Rao K.N., Latha P.S., 2019. Groundwater quality assessment using water quality index with a special focus on vulnerable tribal region of Eastern Ghats hard rock terrain, Southern India. Arabian Journal of Geosciences. 12, 267.
80. Rao N.S., 2006. Nitrate pollution and its distribution in the groundwater of Srikakulam district, Andhra Pradesh, India. Environmental Geology. 51, (4) 631–645.
81. Rasool A., Xiao T., Farooqi A., Shafeeque M, Masood S., Ali S., Fahad S., Nasim W., 2016. Arsenic and heavy metal contaminations in the tube well water of Punjab,Pakistan and risk assessment: Acase study. Ecological Engineering. 95, 90-1000.
82. Rezaei A., Hassani H., 2017. Hydrogeochemistry study and groundwater quality assessment in the north of Isfahan, Iran. Environmental Geochemistry and Health. DOI 10.1007/s10653-017-0003-x.
83. Rouxel M., Mol´enat J., Ruiz L., Legout C., Faucheux M., Gascuel-Odoux C., 2011. Seasonal and spatial variation in groundwater quality along the hillslope of an agricultural research catchment (Western France). Hydrological Processes. 25, 831–841.
84. Saleem M., Ram, S., Mahmood G., 2017. Aquifer Modeling for Identifying the Dry Cells in Greater Noida Region for Rain Water Harvesting. International Journal of Engineering Technology Science and Research. 4, (12) 67-71.
85. Sayadi A.R, Sayadi M.H., Shabant Z., 2011. Irrigation Water Quality in Anar City, Kerman, IRAN based on SAR. Journal of Pollution Research. 30, (2) 257-259.
86. Selvakumar S., Ramkumar K., Chandrasekar N., Magesh N.S., Kaliraj S., 2017. Groundwater quality and its suitability for drinking and irrigational use in the Southern Tiruchirappalli district, Tamil Nadu, India. Applied Water Science. 7, 411–420.
87. Selvam S., Venkatramanan S., Chung S.Y., Singaraja C., 2016. Identification of groundwater contamination sources in Dindugal district of Tamil Nadu, India using GIS and multivariate statistical analyses. Arabian Journal of Geosciences. 9, 407.
88. Shinzato M.C., Hypolito R., 2016. Effect of disposal of aluminium recycling waste in soil and water bodies. Environmental Earth Science. 75, 628.

89. Singh A.P., Rao D.P., 2013. Assessment of tannery effluent: a case study of Kanpur in India. European Chemical Bulletin. 2, (7) 461-463.
90. Singh B., Sekhon G.S., 1976. Nitrate pollution of groundwater from nitrogen fertilizers and animal wastes in the Punjab, India. Agriculture and Environment. 3, (1) 57–67.
91. Singh B., Singh Y., 2004. Balanced fertilization for environmental quality. Fertiliser News, 49, 107–108.
92. Singh C.K., Shastri S., Mukherjee S., 2011. Integrating multivariate statistical analysis with GIS for geochemical assessment of groundwater quality in Shiwaliks of Punjab, India. Environmental Earth Sciences. 62, (7) 1387-1400.
93. Singh S., Hussian A., 2016. Water quality index development for groundwater quality assessment of Greater Noida sub-basin, Uttar Pradesh, India. Cogent Engineering. (3), 1177155.
94. Singh S.K., Ghosh A.K., 2012. Health Risk Assessment Due to Groundwater Arsenic Contamination: Children Are at High Risk. Human and Ecological Risk Assessment. 18, 751–766.
95. Singh U.V., Abhishek A., Singh K.P., Dhakate R., Singh N.P., 2014. Groundwater quality appraisal and its hydrochemical characterization in Ghaziabad (a region of indo-gangetic plain), Uttar Pradesh, India. Applied Water Science. 4, 145–157.
96. Singh V.B., Tripathi J.N., 2016. Identification of Critical Water Quality Parameters Derived from Principal Component Analysis: Case Study from NOIDA Area in India. American Journal of Water Resources. 4, (6) 121-129.
97. Singh V.K., Bikundia D.S., Sarswat A., Mohan D., 2012. Groundwater quality assessment in the village of Lutfullapur Nawada, Loni, District Ghaziabad, Uttar Pradesh, India. Environmental Monitoring & Assessment. 184, 4473–4488.

98. Srivastava S.K., Ramanathan A.L., 2008. Geochemical assessment of groundwater quality in vicinity of Bhalswa landfill, Delhi, India, using graphical and multivariate statistical methods. Environmental Geology. 53, 1509–1528.
99. Su F., Wu J., He S., 2019. Set pair analysis-Markov chain model for groundwater quality assessment and prediction: A case study of Xi’an city, China. Human and Ecological Risk Assessment. 25 (1-2) 158-175.

100. Subramani T., Rajmohan N., Elango L., 2009. Groundwater geochemistry and identification of hydrogeochemical processes in a hard rock region, Southern India. Environmental Monitoring and Assessment. DOI 10.1007/s10661-009-0781-4
101. Tariq S.R., Shah M.H., Shaheen N., Jaffar M., Khalique A., 2008. Statistical source identification of metals in groundwater exposed to industrial contamination. Environmental Monitoring and Assessment. 138, (1-3) 159-165.
102. Tirkey P., Bhattacharya T., Chakraborty S., Baraik S., 2017. Assessment of groundwater quality and associated health risks: A case study of Ranchi city, Jharkhand, India. Groundwater for Sustainable Development. 5, 85–100.
103. Tiwari A.K., Singh A.K., 2014. Hydrogeochemical Investigation and Groundwater Quality Assessment of Pratapgarh District, Uttar Pradesh. Journal Geological Society of India. 83, 329-343.
104. UNEP, Ground Water and its susceptibility to degradation, UNEP/DEWA/ RS.03-3, Nairobi, Kenya, 2003 UNEP.
105. Upadhyay M.K., Majumdar A., Barla A., Bose S., Srivastava S., 2019. An assessment of arsenic hazard in groundwater-soil-rice system in two villages of Nadia district, West Bengal, India. Environmental Geochemistry and Health. https://doi.org/10.1007/s10653-019-00289-4
106. Vaishnav M.M., Dewangan S., 2012. Analytical and statistical evaluation of surface and sub- surface water of BALCO industrial area, Korba, C.G., India. International Journal of Environmental Sciences. 2, (3) 1369-1379.
107. Vasanthavigar M., Srinivasamoorthy K., Vijayaragavan K., Ganthi R.R., Chidambaram S., Anandhan P., Manivannan R., Vasudevan S., 2010. Application of water quality index for groundwater quality assessment Thirumanimuttar sub-basin, Tamilnadu, India. Environment Monitoring and Assessment. 171, (1-4) 595-609.
108. Vijay R., Khobragade P., Mohapatra P.K., 2011. Assessment of groundwater quality in Puri City, India: an impact of anthropogenic activities. Environmental Monitoring and Assessment. 177, (1) 409–418.
109. Vyas P.B., 2011. Assessment of Drinking water quality in Gandhinagar Town, Gujarat, India. Journal of Pollution Research. 30, (2) 161-163.

110. Wirmvem M.J., Ohba T., Fantong W.Y., Ayonghe S.N., Suila J.Y., Asaah A.N.E., Tanyileke G., Hell J.V., 2013. Hydrochemistry of shallow groundwater and surface water in the Ndop plain, North West Cameroon. African Journal of Environmental Science and Technology. 7, (6) 18-530.
111. Wongsanit J., Teartisup P., Kerdsueb P., Tharnpoophasiam P., Worakhunpiset S., 2015. Contamination of nitrate in groundwater and its potential human health: a case study of lower Mae Klong river basin, Thailand. Environmental Science and Pollution Research. 22, 11504–11512.
112. Wu J., Sun Z., 2016. Evaluation of shallow groundwater contamination and associated human health risk in an alluvial plain impacted by agricultural and industrial activities, mid-west China. Expo Health. 8, 311–329.
113. Xu P., Feng W., Qian H., Zhang Q., 2019. Hydrogeochemical Characterization and Irrigation Quality Assessment of Shallow Groundwater in the Central-Western Guanzhong Basin, China. International Journal of Environmental Research and Public Health. 16, 1492. doi:10.3390/ijerph16091492
114. Yadav A., Daulta R., 2014. Effect of Sugar mill on Physico- Chemical Characterstics of Groundwater of Surrounding Area. International Research Journal of Environmental Science. 3, (6) 62-66.

Chapter 3

STUDY AREA

3.1 INTRODUCTION

Gautam Budh Nagar (GBN) district is a part of Uttar Pradesh in northern India. The district Gautam Buddh Nagar was established on 6th May 1997 with effect from government order number 1249/97/82/97 by combining the Dadri & Bisrakh block (parental district Ghaziabad), Dankaur & Jewer block (parental district Bulandshahar) and 18 villages of Bulandshahar. GBN comes under the National Capital Region of India. Administrative headquarters of district are situated in Greater Noida. GBN is administratively divided into three tehsils namely Dadri, Gautam Budh Nagar and Jewar. For development purposes, the district is divided into four blocks – Bisrakh block, Dadri block, Dankaur block and Jewar block. The total number of villages in district GBN is 320. The district shares its boundary with Ghaziabad in north, Delhi in north-west, Faridabad in west and Bulandshahr in east. River Yamuna flows along the west part of district. The district is vertically stretched from north to south rather than east to west.

Gautam Budh Nagar district is a part of Ganga-Yamuna alluvial plain, adjacent to river Yamuna. According to Census (2011), total area of the district GBN is 1282 Km^2 with a population of 1,648,115. Population density of the district (1286 persons/Km^2) is comparatively more than the mean state population of 829 persons/Km^2. The rural population density of district is 616 persons/Km^2 and urban population density is 5,177 persons/Km^2. The sex ratio of females over 1000 males, of the district, is 851 which is less than the mean value of state (912). GBN district comes under Meerut division of Uttar Pradesh. The district is a part of Legislative Assembly seat Dadri and Parliamentary seat of Khurja. Location map of district Gautam Budh Nagar is presented in Fig. 3.1.

Eleven villages of district - Duryai, Talabpur, Khera Dharampura, Bishnuli, Achheja, Dujana, Badalpur, Sadopur, Dairy Maccha, Dhoom Manikpur and Badhpura, were taken under current study. These villages are situated in Bisrakh block (Duryai, Talabpur, Khera Dharampura, Bishnuli, Achheja and Dujana) and Dadri block (Badalpur, Sadopur, Dairy Maccha, Dhoom Manikpur and Badhpura) of the district on the both side of national highway 34. The location of study area is 28°56’19.28’’N

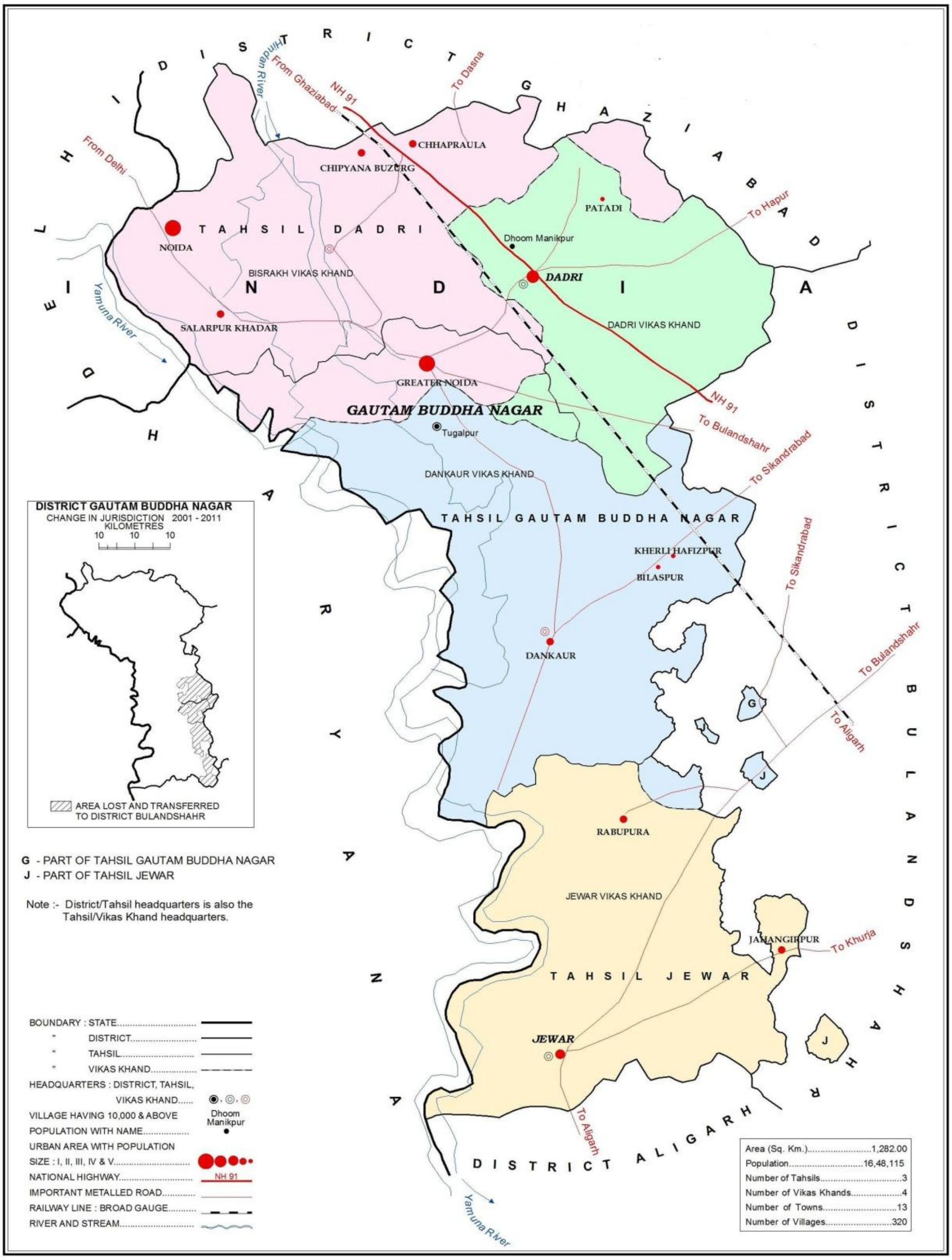


Fig. 3.1 Location Map of District Gautam Budh Nagar (Source : Census 2011)

to 28^{o}63’02.50’’N latitude and 77^{o}47’40.78’’E to 77^{o}54’52.36’’E longitude. Groundwater of twenty-two water quality stations (S1-S22) of these villages was analysed to explore the quality of subsurface water. To assess the impact of waste water originated from different localities, thirteen waste water samples (L1-L13) were also collected from study area. On the basis of land use pattern, area is divided into three zones- Agricultural zone (Duryai, Talabpur), Industrial Zone (Khera Dharampura, Bishnuli, Achheja, Dujana, Badalpur) and Residential Zone (Sadopur, Dairy Maccha, Dhoom Manikpur, Badhpura) (Fig. 3.2).

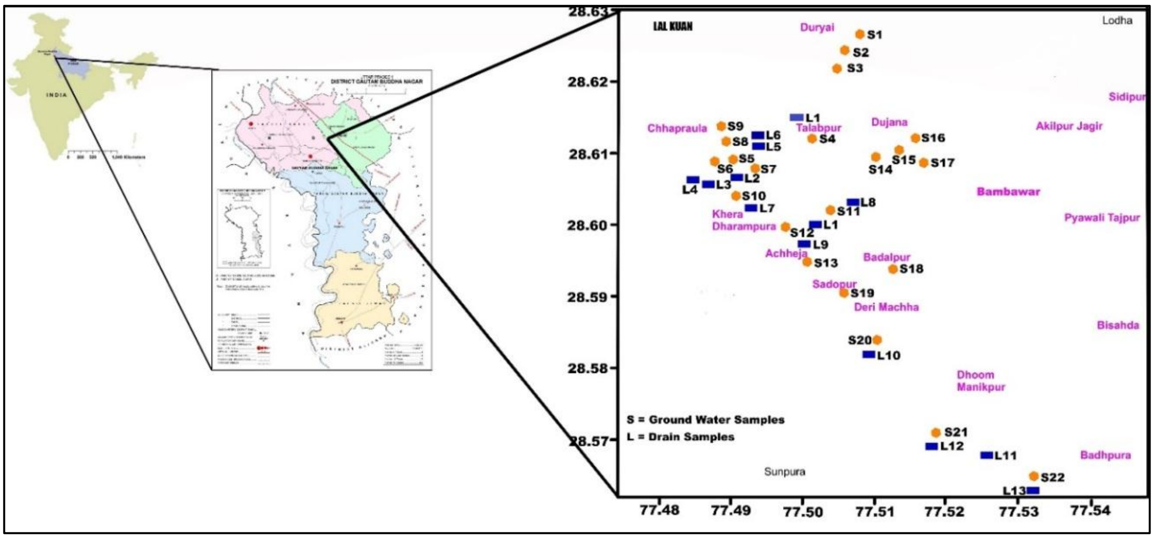


Fig. 3.2 Sampling Locations of Groundwater and Waste water samples

3.2 HISTORY

The splendorous history of the district extends upto TretaYug (Ramayana Kaal). Bisrakh block of the district is the birthplace of Viseswa Rishi (Ravana’s father). In Dwapar Yug (Mahabharat Kaal) Kauravas and Pandavas took training of weapons in Dronacharya’s ashram which was situated in Dankaur. The place was also a home to Eklavaya-the disciple of Dronacharya.

Several national freedom fighter (Sh. Gopi Chand, Sh. Ram Nath, Sh. Harsharan Singh etc.) were also associated from this place. Shaheed Bhagat Singh, Sukh Dev and Rajguru hid in a village Nalgara of GBN.

3.3 PHYSIOGRAPHY

On the basis of natural conditions of geology, soil, climate, topography and vegetation the district is divided into three regions- Yamuna khadar, Dadri plain and Jahangirpur plain.

3.3.1 Yamuna Khadar

Yamuna Khadar region lies in the western part of the district along with the river Yamuna. Major tropical features of the region are small depressions, dead arms of the river and meanders. These depressions have various shapes/sizes and found on the left course of Hindon river. Northern region of the plain has risk of flood as in this area Hindon joins Yamuna river. It is very low-lying area with fertile soil. The slope of the land is very gentle and runs from north to south.

3.3.2 Dadri Plain

North-east part of the district is known by the name- Dadri plain. This plain is slightly lower in the central part than its eastern and western sides but the general slope is towards south. This tract is one of the best agricultural belts of the state. This region belongs to Alluvium and Dun gravels of recent origin.

3.3.3 Jahangirpur Plain

This region covers the eastern and south-central part of the district covering Kakod and Jahangirpur development blocks. It is perfectly a gentle plain with north to south slope. Other physiographic phenomenons are negligible. Entire region is associated with Alluvium and Dun gravels (recent origin). Transport system in this region is well developed.

3.4 DRAINAGE

Two principal rivers that flows along the district are Hindon & Yamuna. These rivers are monsoon fed and flow through the vast tract of the land. The entire district is alluvial region with a general slope of gradient of 0.2 m/km from north-west to south-east direction. River Ganga enters in the district from the north-west boundary whereas river Hindon from middle of north and joins Yamuna within seven kilometer near Dankaur. Except for occurrence of some depressions, the entire plain is marked by large fertile tract. Yamuna is a perennial river. Natural lakes are not found in the district. Seasonal ponds emerge during rainy season and shrink dry during summer.

3.5 Climate and Rain Fall

Climate plays a major role in the geomorphology and soil of that area. Natural vegetation of any area depends upon the climate of that area. Land use pattern of any area is governed by interaction between climate, relief and soils (Vink, 1975). Specifically agricultural development in area (land for agricultural suitability, type of crop and soil productivity) depends upon climate and precipitation. Climate can affect the choice of a crop through many factors such as rainfall pattern, availability of irrigation water, growth duration and pattern of frost (Sherlow, 1971). Temperature majorly determines the growing pattern of crop, intensity of crop, effectiveness of photosynthesis, grain yield of crop and overall productivity. Rainfall is the primary environmental factor which affect growth and yield of crop.

Gautam Budh Nagar district comes under the temperate zone of earth near to tropic of cancer. The entire district experiences sub-tropical climate with extreme temperature. The district has healthy climatic conditions. Being nearer to Delhi, the temperature is akin to that of Delhi. Summers are very warm and dry in hot months of May & June (with maximum temperature ranges from maximum of 48^0C to minimum of 28^0C) but July & August are hot and humid with a maximum temperature of 48^0C. Monsoon season is from month of June to September with a mean rainfall of 395.3 mm. Maximum rainfall occurs in the month of August (upto 205.8 mm). Humidity decreases after the withdrawal of southwest monsoon season. Winter season is from November to February with a minimum temperature of 3^0C to 4^0C. The climate conditions remain very good in the month of February, March, October & November in the district. District rainfall (in millimeters) of last five years is given in Table - 3.1.

Table - 3.1 Rainfall (in millimeters) of five years (2014-2018) of district Gautam Budh Nagar

Year	Jan.	Feb.	March	April	May	June	July	August	Sep.	Oct.	Nov.	Dec.
2014	32	16.5	41.5	8	48	15	27.5	27	67	9	0	9
2015	50	0	77	55	4	59	144	201	0	0	0	0
2016	0	0	0	0	4	4	72	87	150	13	0	0
2017	4	0	7	0	3	69	28	42	151.1	0	0	1
2018	5	0	0	1	0	55	248	46	405	0	0	0

Source : India Meteorological Department (New Delhi)

3.6 SOILS

Geologically the district has three regions- Yamuna khadar, Dadri plain and Jahangirpur plain. The west part of the district has Yamuna khadar area. This part also has sand dunes, sandy ridges and depressions. Many ravenous tracts are also developed near river Yamuna due to soil erosion. The soil type of the district is the combination of sand and clay. Major portion of the district has clay loam soil (52%), nearly 24% part has loamy soil and 18% part has sandy loam soil (Fig. 3.3; Agriculture Contingency Plan for District: Gautam Budh Nagar). Highly fertile domat soil is found in the west part of the district with patches of barren land. Due to fertile soil, availability of human resources and various sources for irrigation, the major part of land (67.93%) is used for agricultural practices (Joshi, 2009). Industrial development has been occurred in recent years but still agriculture is primary source of income for most of the residents of the district. Land use pattern of district Gautam Budh Nagar is given in Table - 3.2

Legend

Alluvial plain (0-1% slope)

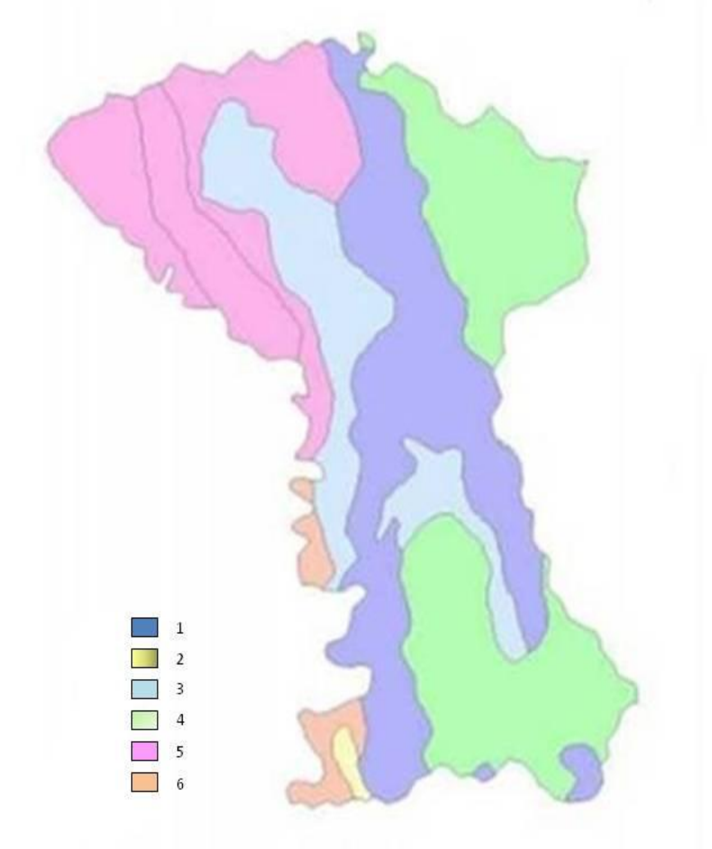
1. Deep, loamy soils .
2. Deep, loamy soils and slightly eroded associated with silty soils.
3. Deep, fine soils moderately saline and sodic associated with loamy soils, slightly eroded.
4. Deep, silty soils and slightly eroded associated with loamy soils slightly saline and slightly sodic.

Old alluvial plain with river left out channels /Oxbows/point bars (1-3% slope)

5. Deep, loamy soils and slightly eroded associated with stratified loamy soils slightly eroded.

Recent alluvial plain (1-3% slope)

6. Deep, loamy soils slight salinity and sodicity associated with loamy soils are slightly eroded.



Source : Agriculture Contingency Plan for District: Gautam Budh Nagar

Fig. 3.3 Soil map of District Gautam Budh Nagar

Table - 3.2 Land-use Pattern of District Gautam Budh Nagar

Land-Use pattern of District	Area (in hectares)
Geographical area	125.4
Cultivable area	82.1
Forest area	2
Land under non-agricultural use	24
Permanent pastures	0.5
Cultivabale wasteland	2.5
Land under Miscellaneous tree crops and groves	0.4
Barren and Uncultivable land	3.4
Current fallows	2.4
Other fallows	7.8

Source : Agriculture Contingency Plan for District: Gautam Budh Nagar

3.7 GROUNDWATER STATUS

3.7.1 Water Bearing Formation

The rocks underlying the sedimentary sequence is explored upto the level of 352 m in the district (District Survey Report of Minor Minerals, 2017). A good ground aquifer system is formed due to alluvial deposits of Ganga and Yamuna. This underground aquifer is granulated (fine to coarse sand). The role of thick clay bed interposed with sand is to act as confining layer and the aquifers are separated by them. As we move towards east there is an increase in the thickness of unconsolidated sediments.

3.7.2 Occurrence of Ground Water

Upto the depth of 100 mbgl (meters below ground level), ground water is found in phreatic conditions and in subsequent aquifers, it is present in confined to semi-confined conditions.

3.7.3 Depth to Water Level

On the basis of water level data monitored in pre-monsoon and post-monsoon season, district can be divided into different zones. The range of water level in phreatic aquifer is from a minimum of 3.35 to a maximum of 14.40 mbgl during pre-monsoon period. This range falls down to 2.00 - 13.95 mbgl during post monsoon period. At most of the non- command areas water level is greater than 9 mbgl. Few deeper water levels (> 9 mbgl) are found in east of Jhajhar (Dankaur Block), Dadri area and along Yamuna river. This signifies the deepening of water levels toward river. Saleem et al., (2017) analysed 27 active piezometric wells in Greater Noida region and found the least water level at Rampur Mazra (2.10 m) & the highest degree of water level at Tachzone-4 (10.8 m).

3.7.4 Seasonal Water Level Fluctuation

After analyzing the data obtained from the groundwater monitoring wells, it is concluded that seasonal fluctuation occurred in ground water level. The amount of rainfall and geographical conditions of the area is responsible for the variation in water level. The inflow along with the outflow of ground water is controlled by many factors including natural flow of rivers, loss through evaporation, leakage from canal etc. A rise in water level (from 0.12 to 3.69 mbgl) is recorded from majority of the wells during post-monsoon season which indicate the recharging of ground aquifers. However in some wells lowering of water level (from 2.76 to 0.09 mbgl) has been reported after precipitation. From the data obtained from national hyrdograph stations, from 1977 to 2006, a decline in water level in post-monsoon season has been reported in Jewar, Dankaur and Dadri tehsil which indicates stress on ground resources (Central Ground Water Board, Annual Report, 2008-2009). These areas are semi-urban areas and people are largely dependent upon groundwater resources for their daily requirements and irrigational water.

3.7.5 Groundwater Resources

The scenario of ground water resources assessed by using GEC (Groundwater Resources Estimation Methodology, 1997) formulated by Central Ground Water Board and State Ground Water Department on 31st March 2004 is given in Table – 3.3 (Dynamic Groundwater Resources of India, as on March 2004).

Table - 3.3 Blockwise Report of Ground Water Resources

S No.	Blocks	Annual Groundwater recharge (in ham)	Net Annual Groundwater availability (in ham)	Existing Gross Groundwater draft for all uses (in ham)	Net Groundwater availability for future irrigation (in ham)	Stage of Groundwater development (in %)	Category of Block
1	Bisrakh	9528.38	9051.96	6756.76	2079.39	74.64	Safe
2	Dadri	20355.50	19337.73	5024.83	14155.37	25.98	Safe
3	Dankaur	17673.36	16789.69	9762.34	6933.23	58.14	Safe
4	Jewar	15509.17	14733.71	9248.54	5424.44	62.77	Safe
	Total	63066.42	59913.10	30792.48	28592.44	51.40	

Source : District brochure of Gautam Budh Nagar, Uttar Pradesh, 2009

*ham: Hectare meter

REFERENCES

1. Agriculture Contingency Plan for District: Gautam Budh Nagar, Uttar Pradesh, Central Research Institute for Dryland Agriculture (CRIDA).
2. Census, 2011. District Gautam Buddha Nagar, Uttar Pradesh, Government of Uttar Pradesh.
3. Central Ground Water Board, Annual Report 2008-2009. Ministry of Water Resources Government of India.
4. District Survey Report of Minor Minerals, Nov. 2017. Gautam Budh Nagar District, Notification No. S.O. 141 (E) New Delhi, 15th January, 2016 of Ministry of Environment, Forest and Climate change.
5. Dynamic Groundwater Resources of India (as on March 2004). Central Ground Water Board, Ministry of Water Resources Government of India, 2006.
6. India Meteorological Department, Customized Rainfall Information System (CRIS), Hydromet Division, Ministry of Earth Sciences, New Delhi
7. Joshi B.C., 2009. Central Groundwater Board. District brochure of Gautam Budh Nagar, Uttar Pradesh.
8. Saleem M., Ram S., Mahmood G., 2017. Analysis of Ground Water Quantity Improvement in Greater Noida Region using Rain Water Harvesting System: A Research Article. International Journal of Engineering Technology Science and Research. 4, (10) 2394 – 3386.
9. Sherlow D.S., 1971. Agricultural Geography of Great Britain, Oxford, Perganon Press. p. 20.
10. Vink A.P.A., 1975. Landuse in Advancing Agriculture, New York, Springer-Venlag. p. 8.

Chapter 4

MATERIAL & METHODS

4.1 INTRODUCTION

Agriculture remained the main occupation of people of district GBN but in last decade several industries are established here. These industries need a plenty of water. Extraction of groundwater is increasing to fulfill industrial demand of fresh water. Due to change in land use pattern, a lot of waste water is originated from the industrial activities. According to census, (2011) total population of GBN has been increased by 5,48,115 from 2001 to 2011. The amount of domestic waste water is also increased due to such increase in population. High rate of extraction of groundwater and generation of huge amount of waste water, negatively affects the water quality.

4.2 METHODOLOGY

Methods used for current study are summarized under following headings-

4.2.1 Field study and preliminary survey

4.2.2 Systematic collection of Groundwater and Waste water Samples

4.2.3 Testing of physico-chemical parameters and heavy metals using methods of APHA 22nd edition (2012)

4.2.4 Water quality suitability for drinking

4.2.5 Water quality suitability for irrigation

4.2.6 Impact of waste water on groundwater quality

4.2.7 Water quality index

4.2.8 Geographical information system (GIS) map for groundwater quality

4.2.9 Defluoridation of aqueous solution using marble slurry

Flow diagram of methodology used is given in Fig. 4.1.

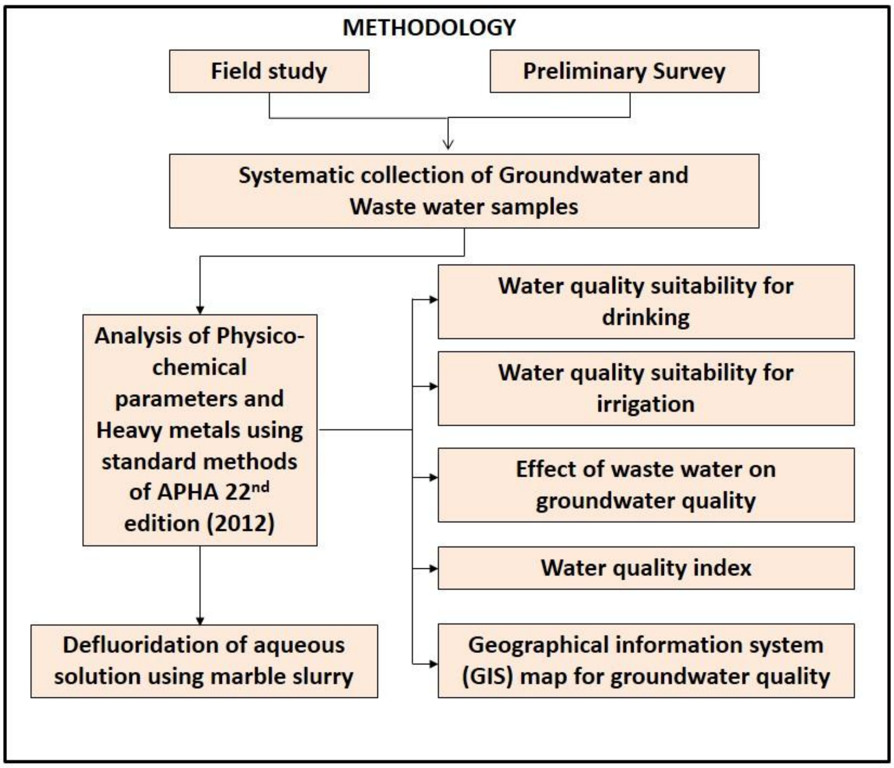
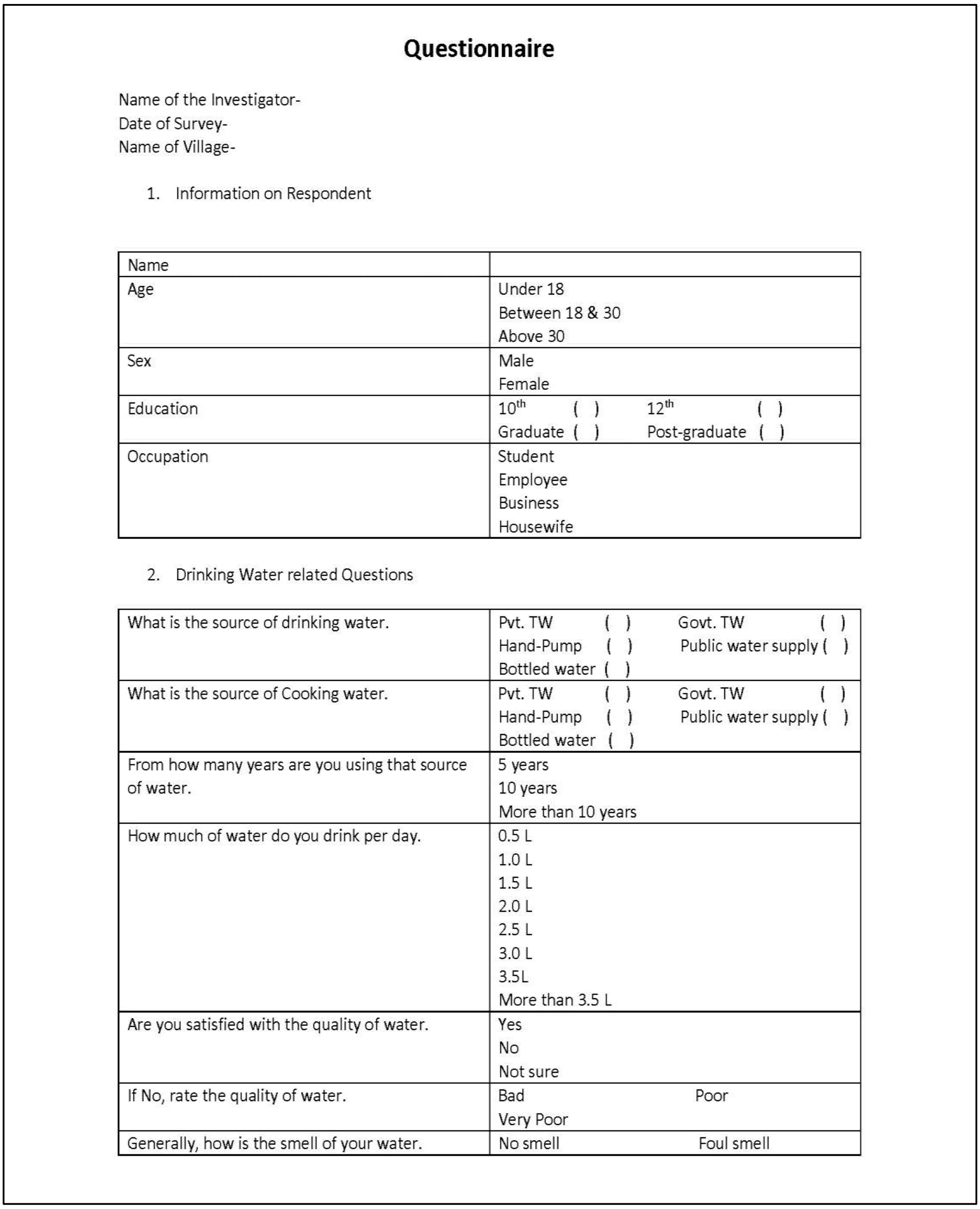


Fig. 4.1 Flow Chart of used Methodology

4.2.1 Field Study and Preliminary Survey of Area

Study area was surveyed to identify the location for groundwater and waste water sampling. Local inhabitants were interviewed to understand the issues related to groundwater quality. On the basis of preliminary survey of study area, twenty two sites were identified for groundwater sampling and thirteen sites for waste water sampling. A questionnaire was prepared, which was given to residents of selected sites. The residents were asked about water quality and problem related to that. Health related problems of residents were also asked using simple terms to get reliable information. Inhabitants were also asked about their economic status to find relationship between health problems and economy. A total of 32 questionnaire reports were selected for further study. A pro forma of questionnaire is shown in Fig. 4.2.



Questionnaire

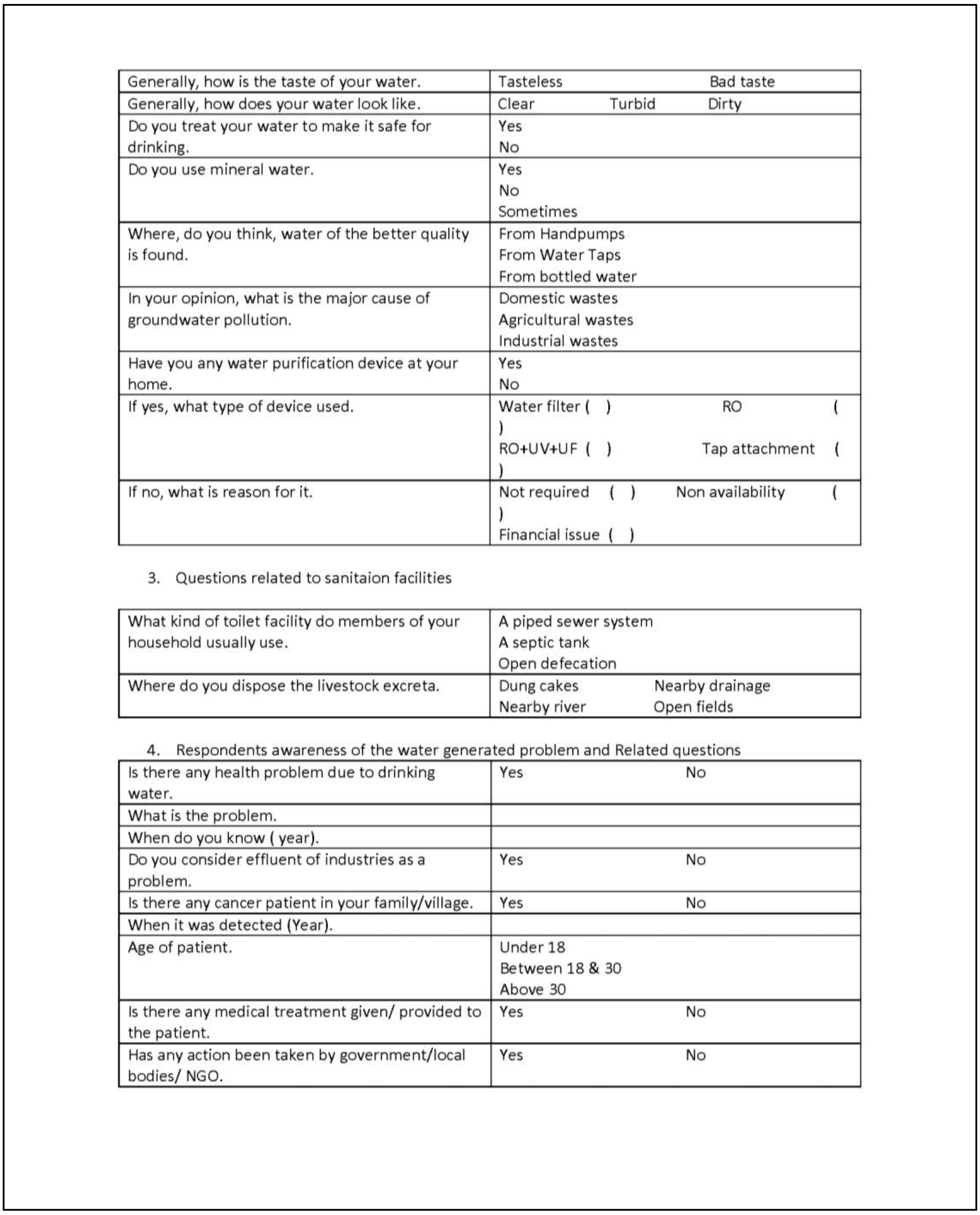
Name of the Investigator-
Date of Survey-
Name of Village-

1. Information on Respondent

Name	
Age	Under 18 Between 18 & 30 Above 30
Sex	Male Female
Education	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes No Not sure
If No, rate the quality of water.	Bad Poor Very Poor
Generally, how is the smell of your water.	No smell Foul smell



Generally, how is the taste of your water.	Tasteless Bad taste
Generally, how does your water look like.	Clear Turbid Dirty
Do you treat your water to make it safe for drinking.	Yes No
Do you use mineral water.	Yes No Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes Industrial wastes
Have you any water purification device at your home.	Yes No
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system A septic tank Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes No
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem.	Yes No
Is there any cancer patient in your family/village.	Yes No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes No

Fig. 4.2 Pro Forma of questionnaire used in Survey

4.2.2 Systematic Collection of Groundwater and Waste Water Samples

Samples of groundwater and waste water were collected in new pre-washed 1000 ml high-density polypropylene (HDP) sampling bottles. Prior to sampling, containers were soaked in 10% HNO_3 for one day and thereafter carefully rinsed with double distilled water. After washing, sample containers were dried at 50^0C for 6 hrs. Groundwater samples were taken from various hand-pumps and tube-wells. Waste water samples were collected from drains coming from agricultural, industrial and residential areas. Sampling was done in pre-monsoon season (in the month of June) and post-monsoon season (in the month of October) of consecutive three years - 2016, 2017, 2018. Sample code and geographical coordinates of sampling sites are presented in Table – 4.1 & 4.2. Sampling locations of groundwater and waste water samples are given in Fig. 3.2.

For trace metal analysis representative samples of groundwater and waste water were collected in duplicate in pre-washed polypropylene bottles as stated for the sample collection for physico-chemical analysis. 5 ml of concentrated HNO_3 was added to 1 litre sample immediately after collection. Acidified sample was pre-concentrated by evaporation over steam bath. One litre of the acidified sample was reduced to 25 ml volume and kept for Atomic Absorption Spectrophotometer (AAS) analysis.

For ions and metal analysis, chemicals of analytical reagent (AR) grade were used. Standard solutions of metal ions were purchased from Merck, Germany. Standards and buffers for ion-selective electrodes were purchased from Thermo Scientific Company. Double distilled water was used in chemical analysis. All glass-wares were made up of borosil and thoroughly cleaned by lavoline detergent. They were kept immersed in 10% HNO_3 for 2 days and then washed with double distilled water several times.

Table – 4.1 Geographical Coordinates of Groundwater Sampling Locations

Groundwater Sample code	Sampling Locations/Water Quality Stations	Zone	Geographical Coordinates	
			Latitude	Longitude
S1	Duryai	Agricultural Zone	28.630250^{0}N	77.501759^{0}E
S2	Duryai		28.629868^{0}N	77.502253^{0}E
S3	Duryai		28.627330^{0}N	77.501697^{0}E
S4	Talabpur		28.619033^{0}N	77.494481^{0}E
S5	Bisrakh Road	Industrial Zone	28.621712^{0}N	77.481314^{0}E
S6	Bisrakh Road		28.617732^{0}N	77.474078^{0}E
S7	Bisrakh Road		28.620726^{0}N	77.477270^{0}E
S8	Bisrakh Road		28.622160^{0}N	77.478065^{0}E
S9	Bisrakh Road		28.621566^{0}N	77.481863^{0}E
S10	Khera Dharampura		28.614651^{0}N	77.490040^{0}E
S11	Bishnuli		28.612011^{0}N	77.493143^{0}E
S12	Achheja		28.598881^{0}N	77.501944^{0}E
S13	Achheja		28.600464^{0}N	77.505047^{0}E
S14	Dujana		28.602260^{0}N	77.504826^{0}E
S15	Dujana		28.606913^{0}N	77.507652^{0}E
S16	Dujana		28.615876^{0}N	77.511130^{0}E
S17	Dujana		28.613977^{0}N	77.512070^{0}E
S18	Badalpur		28.597320^{0}N	77.508607^{0}E
S19	Sadopur	Residential Zone	28.585927^{0}N	77.512238^{0}E
S20	Dairy Maccha		28.583721^{0}N	77.522888^{0}E
S21	Dhoom Manikpur		28.566837^{0}N	77.539232^{0}E
S22	Badhpura		28.561928^{0}N	77.545236^{0}E

Table – 4.2 Geographical Coordinates of Waste water Sampling Locations

Waste Water Sample code	Sampling Locations	Zone	Geographical Coordinates	
			Latitude	Longitude
L1	Talabpur	Agricultural Zone	28.615444^0N	77.489863^0E
L2	Bisrakh Road	Industrial Zone	28.621712^0N	77.481314^0E
L3	Bisrakh Road		28.617732^0N	77.474078^0E
L4	Bisrakh Road		28.616432^0N	77.472733^0E
L5	Bisrakh Road		28.620726^0N	77.477270^0E
L6	Bisrakh Road		28.622160^0N	77.478065^0E
L7	Khera Dharampura		28.610187^0N	77.494824^0E
L8	Bishnuli		28.608787^0N	77.496408^0E
L9	Achheja		28.600464^0N	77.505047^0E
L10	Dairy Maccha	Residential Zone	28.583721^0N	77.522888^0E
L11	Dhoom Manikpur		28.563341^0N	77.543545^0E
L12	Dhoom Manikpur		28.566837^0N	77.539232^0E
L13	Badhpura		28.561928^0N	77.545236^0E

4.2.3 Testing of Physico-Chemical Parameters and Heavy Metals

Physico-chemical parameters and trace metals were quantitatively analysed in all the collected groundwater and waste water samples. Standard methods of American Public Health Association (APHA) 22nd edition, 2012 were used for analysis. Analytical procedures for various parameters are given in Table - 4.3.

Table – 4.3 Analytical Procedure for Different Parameters

S. No.	WQ Parameter	Method	Description of Method
1	pH	APHA 22nd Ed.2012- 4500H^+B (Electrometric Method)	The pH of the samples is measured by pH meter with combined glass electrode. The measurements are done by calibrating the pH meter with buffers of pH=7.0, pH=10.0 and pH = 4.0 at room temperature.
2	Electrical Conductivity	APHA 22nd Ed.2012 -2510 B (Laboratory Method)	Electrical conductivity is measured in µmhos/cm unit in the laboratory by conductivity meter Orion-013005MD Dura Probe 4. Before measurement, instrument was properly calibrated by potassium chloride solution (0.01 M).
3	Total Dissolved Solids	APHA 22nd Ed.2012 -2540 C (Total Dissolved Solids dried at 180^0C)	The water sample after filtration is evaporated in a porcelain dish to dryness using an air circulated oven at around 105^0C. Then it is cooled in a dessicator and weighed. It is expressed in mg/L. The weighing should be done very quickly because atmospheric moisture can change the weight of the porcelain dish.
4	Turbidity	APHA 22nd Edn.2012 –2130 B	Turbidity is measured in NTU. Calibration of nephlometer is done using standard turbidity suspension of 40 NTU turbidity. Stock

Table – 4.3 Analytical Procedure for Different Parameters

S. No.	WQ Parameter	Method	Description of Method
		(Nephelometric Method)	turbidity suspension is prepared by mixing 5 ml of solution I (hydrazine sulphate; $(NH_2)_2.H_2SO_4$) and 5 ml of solution II (hexomethylenetetramine; $(CH_2)_6N_4$) in a 100 ml volumetric flask.
5	Total Hardness as $CaCO_3$	APHA 22nd Ed.2012 -2340 C (EDTA Titrimetric Method)	Total hardness is analysed by (Ethylenediaminetetraacetic acid) EDTA complexometric titration. Titrant used – chelating agent EDTA, Indicator used - Erichrome Black T. End point- change of colour from wine red to steel blue.
6	Calcium as Ca^{+2}	APHA 22nd Ed.2012 -3500 Ca-B (EDTA Titrimetric Method)	Calcium is also analysed by EDTA complexometric titration method. To avoid interference of magnesium, pH of the analysed sample was kept high (12-13). At this pH magnesium was precipitated as hydroxide and did not react with EDTA. Indicator used - Murexide.
7	Magnesium as Mg^{+2}	APHA 22nd Ed.2012 -3500 Mg-B (Calculation Method)	Magnesium content is analysed by subtracting Ca from Ca + Mg.
8	Sodium as Na^+	APHA 22nd Edn.2012 -3500 Na-B (Flame Emission Photometric Method)	Sodium is measured with flame photometer (Systronics -128). Calibration of instrument is done with standards solution of sodium of concentration 50, 40, 30, 20, 10 mg/L. The instrument gives directly the values of sodium in mg/L.
9	Potassium as K^+	APHA 22nd Edn.2012 -3500 K-D (Flame Emission Photometric Method)	Potassium is measured with flame photometer (Systronics -128). Calibration of instrument is done with standard solution of potassium of concentration 2.5, 5, 7.5, 10, 15 mg/L. The instrument gives directly the values of potassium in mg/L.
10	Total Alkalinity as $CaCO_3$	APHA 22nd Ed.2012 -2320 B (Titration Method)	25 ml of the water sample is titrated against 0.02N sulfuric acid solution. Indicator used - phenolphthalein (for carbonate alkalinity) and methyl orange (for bicarbonate alkalinity). Total alkalinity is expressed in mg/L as $CaCO_3$ equivalent.
11	Chloride as Cl^-	APHA 22nd Ed.2012 -4500 Cl^- B (Argentometric Method)	It is measured by argentometric method. If the sample is turbid, it is mixed with aluminium hydroxide $Al(OH)_3$ suspension, settled and filtered to remove interference and then titrated against standard $AgNO_3$ with K_2CrO_4 as indicator. The mixing during the titration is done with a magnetic stirrer and the end point is marked by a pinkish yellow coloration. 0.0141M standard silver nitrate solution is used which is standardized by using sodium chloride solution of same concentration.
12	Sulphate	APHA 22nd Ed.2012 -4500 SO_4^{-2} E (Turbidimetric Method)	Sulphate Ion is measured by turbidimetric method by using spectrophotometer. Quantitatively sulphate ions are measured from the absorbance of the light by barium sulphate (precipitated by adding barium chloride in acetic acid medium buffer) and then comparing it with a standard curve.
13	Fluoride	APHA 22nd Ed.2012 -4500 F^- C (ISE method)	Solid state combination electrode (9609 BNWP) is used for the analysis of fluoride as recommended by APHA.
14	Ammonium nitrogen	APHA 22nd Ed.2012 -4500 NH_3-D	Ammonium nitrogen of water samples is analysed by ion selective electrode method as recommended by APHA.

Table – 4.3 Analytical Procedure for Different Parameters

S. No.	WQ Parameter	Method	Description of Method
		(Ammonia ISE method)	
15	Nitrite	APHA 22nd Ed.2012 -4500 NO_2^-B (Colorimetric Method)	Nitrite ion is measured through diazonium coupling reaction. A reddish purple azo dye is produced at pH 2.0 - 2.5 by compiling diazotized sulphanilic acid with N-(1-Naphthy) ethylenediamine dihydrochloride (NED - dihydrochloride).
16	Nitrate as NO_3 as N	APHA 22nd Ed.2012 -4500, NO_3^- D (Nitrate Electrode Method)	Nitrate nitrogen in mg/L is directly measured by ion selective meter using nitrate ion-selective electrode.
17	Phosphate	APHA 22nd Ed.2012 -4500 P-E (Ascorbic Acid Method)	The phosphate concentration is measured by ascorbic method after sulphuric acid-nitric acid digestion. 25 ml of the sample is digested with concentrated H_2SO_4 (1ml) and concentrated HNO_3 (5ml) cooled and neutralized with NaOH using phenolphthalein indicator. Absorbance is measured at 880 nm after 10 to 20 minutes of the addition of 8 ml combined reagent (50ml 5N H_2SO_4 + 5 ml antimony potassium tartrate solution + 15 ml ammonium molybdate solution + 30 ml ascorbic acid solution).
18	Boron	APHA 22nd Ed.2012 -4500B/B (Curcumin Method)	Sample is acidified with HCl and evaporated with curcumin solution (a dye extract form turmeric), in the presence of oxalic acid to provide reducing condition when a red coloured complex rosocyanine is formed. The colour product is dissolved in ethyl alcohol/isopropyl alcohol and absorption is measured at 540 nm wavelengths in spectrophotometer.

Atomic Absorption Spectrophotometer (AAS) technique was used for heavy metal analysis to determine metal concentration upto ppb (parts per billion) level. Agilent 240 FS atomic absorption spectrophotometer was calibrated with standard solutions of that metal (of known concentration), to obtain standard curve. This standard curve was used for quantitative analysis of metals according to Beer's law. Air - Acetylene gas was used for metal analysis. Standard solution was also tested periodically with water samples. The metal contents of collected samples were examined according to standard procedure of APHA, 2012. Instrument consists of three main unit- Flame atomizer, VGA (Vapour Generation Assembly; used for the analysis at ppm level) and GTA (Graphite tube Atomizer; detects metal ions at ppb level). Atomic absorption hollow cathode lamps are filled with neon gas except Cs, Lu and Al/Ca/Mg lamps, which are filled with argon. The wave length, current, and slit width used for each metal are given in Table - 4.4.

Table – 4.4 Operating Conditions for Metal Analysis by Atomic Absorption Spectrophotometer

S. No.	Metals	Wave length (nm)	Current (mA)		Slit width (nm)	Window Material	Methods used for Analysis
			Recommended	Maximum			
1	Arsenic	193.7	10	12	0.5	Fused Silica	AAS with VGA
2	Cadmium	228.8	4	10	0.5	Fused Silica	AAS with GTA
3	Chromium	357.9	7	15	0.2	Pyrex	
4	Copper	324.8	4	10	0.5	Fused Silica	
5	Lead	217	10	12	1.0	Fused Silica	
6	Nickel	232	4	10	0.2	Fused Silica	
7	Zinc	213.9	5	10	1.0	Fused Silica	AAS with Flame Atomizer
8	Iron	248.3	7	10	0.2	Fused Silica	

4.2.4 Water Quality Suitability for Drinking

Quality of water is a matter of great importance when it is directly consumed by human beings. Most of the countries put forward a criteria for safe drinking water. In India, Bureau of Indian Standards (BIS) has articulated various standard parameters for drinking water. Internationally, drinking water standard, given by World Health Organization (WHO), has been accepted widely. Specific drinking water standards given by BIS and WHO are given in Table – 4.5. Drinking quality of groundwater samples were also assessed through water quality index.

Table – 4.5 Standard value of parameters in Drinking Water given by BIS and WHO

S. No.	Parameters	BIS 10500:2012		WHO (2017)
		Acceptable Limit	Permissible Limit	
1	pH	6.5-8.5	-	6.5-8.5
2	Electrical Conductivity (µmhos/cm)	-	-	-
3	TDS (mg/L)	500	2000	600
4	Turbidity (NTU)	1	5	-
5	Calcium as Ca^{+2} (mg/L)	75	200	100-300 (Taste threshold)
6	Magnesium as Mg^{+2} (mg/L)	30	100	-
7	Sodium as Na^{+} (mg/L)	-	-	200 (Taste threshold)
8	Potassium as K^{+} (mg/L)	-	-	-
9	Boron (mg/L)	0.5	1	2.4
10	TH as $CaCO_3$ (mg/L)	200	600	-
11	TA as $CaCO_3$ (mg/L)	200	600	-
12	Chloride (mg/L)	250	1000	200-300 (Taste threshold)
13	Fluoride (mg/L)	1	1.5	1.5
14	Sulphate (mg/L)	200	400	250 as Na_2SO_4 1000 as $CaSO_4$
15	Ammonia as total ammonia-N (mg/L)	0.5	-	1.5 (Odour threshold)
16	Nitrite (mg/L)	-	-	3
17	Nitrate (mg/L)	45	-	50
18	Phosphate (mg/L)	-	-	-
19	Arsenic (mg/L)	0.01	0.05	0.01
20	Cadmium (mg/L)	0.003	-	0.003
21	Chromium (mg/L)	-	-	0.05
22	Copper (mg/L)	0.05	1.5	2
23	Lead (mg/L)	0.01	-	0.01
24	Nickel (mg/L)	0.02	-	0.07
25	Zinc (mg/L)	5	15	4 (Taste threshold)
26	Iron (mg/L)	0.3	-	-

4.2.5 Water Quality Suitability for Irrigation

Similar to drinking water quality standards, irrigation quality criteria for water has also been developed. Most of the countries have accepted the criteria formulated by the USDA classification (Richards, 1954; National Engineering Handbook, part 623, 2013). Two important characteristics of irrigation water: salinity and sodium hazard, are taken into consideration in this criteria.

From the analytical results, the acceptability of groundwater for agricultural uses was examined according to electrical conductivity (EC), sodium percentage (Na%), sodium absorption ratio (SAR), residual sodium carbonate (RSC), permeability index (PI), magnesium hazard (MH), kelly index (KI) and boron toxicity. These parameters were calculated by using the measured ionic strength of calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride and sulphate in mill equivalents per litre.

Salinity of water is caused by total dissolved salts present in it. Salinity of water is best determined by electrical conductivity as it reflects the total amount of dissolved salts. On the basis of electrical conductivity, four categories of water is defined (Table – 4.6). The salinity of irrigation water produces different hazard on different type of soil.

Table – 4.6 Suitability of Irrigation Water According to Electrical Conductivity

S. No	Electrical conductance (µmho/cm)		Water Class	Suitability
	Grade	Range		
1	Low Salinity	<250	Excellent	This type of water can be used for any type of crop and on any type of soil. Slight leaching is required to avoid soil salinity but it happens under normal agricultural conditions.
2	Medium Salinity	250-750	Good	With this type of water a considerable amount of leaching is required. It can be used for irrigation of moderate salt tolerance plants without any special practices of leaching and drainage.
3	High Salinity	750-2250	Fair	Special salinity control techniques and proper drainage are required with this type of water. High salt tolerance crops are recommended for cultivation in those areas where only highly saline water is available for irrigation.
4	Very High Salinity	>2250	Unsuitable	This type of water is not suitable for irrigation. But in absence of alternative sources for irrigation, it can be used with highly permeable soil, proper drainage, and excessive application of irrigation water and with very high salt tolerance crops.

Sodium hazard of irrigation water is analysed in terms of sodium absorption ratio (SAR) (Todd, 1980). Amount of sodium in soil depends upon the SAR value of irrigation water. Quantity of sodium present in soil greatly affects the physical condition of soil. High content of sodium in soils, results into formation of crusts, lesser soil aeration, lesser infiltration rate, water logging and lesser soil permeability. Few crops are critically sensitive to sodium present in soil. Suitability of irrigation water on the basis of SAR is given in Table - 4.7.

Table – 4.7 Suitability of Irrigation Water According to Sodium Adsorption Ratio (Sodium Hazard)

S. No	Sodium Adsorption Ratio		Water Class	Suitability
	Grade	Range		
1	Low Sodicity	<10	Excellent	This type of irrigation water can be used for every kind of crop with all soils. There is no risk of sodicity with this irrigation water. However few sodium- sensitive plants like stone- fruit trees and avocado may accumulate a great quantity of sodium.
2	Medium Sodicity	10 to 18	Good	This type of irrigation water may be used on coarse soil with good permeability. But on fine soil with lesser permeability, it causes sodium hazard.
3	High Sodicity	18 to 26	Fair	This type of water is not suitable for both type of soil – fine textured & coarse textured. Special agricultural practices – proper drainage, good leaching and organic soil, are required to control the amount of sodium in soil. Addition of gypsum avoids development of harmful quantity of exchangeable sodium from such type of water. Chemical amendments can also be used to manage the quantity of sodium in soil with low saline water.
4	Very High Sodicity	>26	Poor	This type of water is not suitable for irrigation purposes except at low and medium salinity water. Chemical amendments are required to make the use of this water feasible.

4.2.6 Effect of Waste Water on Groundwater Quality

To know the effect of waste water on groundwater quality, characterization of waste water originated from agricultural area, industrial area and residential area was also done. Standards for specific parameters for effluent discharge are given in Table – 4.8 (General standards for discharge of environmental pollutants, 1986).

Table – 4.8 General Standards for discharge of Environmental Pollutants

Parameters	Standards			
	Inland surface water	Public Sewers	Land for Irrigation	Coastal areas
pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
Suspended Solids (mg/L)	100	600	200	For process waste water-100. For cooling water effluent-10% above TSS of influent.
Particulate size of suspended solids	pass through 850 µ IS Sieve	-	-	Floatable solids- maximum 3 mm. Settleable solids- maximum 850 µ.
Free Ammonia (mg/L)	5	-	-	5
Fluoride (mg/L)	2	15	-	15
Arsenic (mg/L)	0.2	0.2	0.2	0.2
Chromium (mg/L)	2	2	-	2
Cadmium (mg/L)	2	1	-	2
Lead (mg/L)	0.1	1	-	2
Copper (mg/L)	3	3	-	3
Zinc (mg/L)	5	15	-	15
Nickel (mg/L)	3	3	-	5
Iron (mg/L)	3	3	-	3

4.2.7 Water Quality Index

Water Quality Index is a mathematical value for drinking quality of water which includes the concentration of a number of constituents present in it. Chemical and biological measures of water quality are used to represent water quality index. Measured value of the selected quality parameter, ideal concentration of that parameter in pure water and standard value given by different quality control organizations are used to determine water quality index. In the current research three indexing methods Weighted Arithmetic Water Quality Index (WAWQI), Groundwater Quality Index (GWQI) and Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) were used to calculate water quality index of groundwater (Table – 4.9).

Table – 4.9 Water quality rating as different water quality index method

Water Quality Index Level	Water Quality Status
As Weighted Arithmatic Water Quality Index (WAWQI)	
0-25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Unsuitable for Drinking
As Groundwater Quality Index (GWQI)	
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking
As Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)	
0-44	Poor Water Quality
45-59	Marginal Water Quality
60-79	Fair Water quality
80-94	Good Water Quality
95-100	Excellent Water Quality

4.2.8 Geographical Information System (GIS) for Groundwater Quality

Geographical information system (GIS) maps are best way to describe groundwater quality in any region. In current study, GIS maps were prepared for each analysed parameters for groundwater quality using software Surfer 11.

4.2.9 Defluoridation of Aqueous Solution Using Marble Slurry

Extreme fluoride concentrations in drinking water persist to be a grave problem in many parts of the world. Due to such manifestations there was a demand of simple yet cost effective method for defluoridation. Current study puts forward an alternative cost effective method of defluoridation using marble slurry as an adsorbent. Batch experiments were conducted in order to evaluate the parameters, which judge the adsorption process, and removal efficiency of adsorbent.

REFERENCES

1. American Public Health Association (APHA), 2012. Standard methods for examination of water and wastewater. 22nd ed., Washington DC. APHA, AWWA, WPCF.
2. Bureau of Indian Standards (BIS), 2012. Indian standard specification for drinking water (IS:10500). Manak Bhawan, New Delhi, India.
3. Census, 2011. District Gautam Buddha Nagar, Uttar Pradesh, Government of Uttar Pradesh.
4. General standards for discharge of environmental pollutants, 1986. Part- A, Effluents, Schedule-VI, The Environment (Protection) Rules.
5. National Engineering Handbook, part 623, 2013. United States Department of Agriculture. Natural Resources Conservation Service.
6. Richards L.A., (Ed). 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Hand Book, No., 60,160.
7. Todd D.K., 1980. Groundwater Hydrology. 2nd ed., John Wiley and Sons, New York, pp. 535.
8. World Health Organization (WHO), 2017. Guidelines for drinking-water quality, (4th ed. incorporating the first addendum), World Health Organisation, Geneva.

Chapter 5

RESULTS & DISCUSSION

A survey was conducted in study area to know the health issues among the residents. A total of 35 people were asked about the drinking water quality and health related questions. Out of these, 32 survey reports were included in study (Fig. 5.1.1 & 5.1.2). People of eight villages were interviewed. Results of survey showed that residents of two villages (Duryai & Talabpur) of agricultural zone didn't have any major health problem. Many residents of three villages (Achheja, Dujana & Badalpur) of industrial zone had gastro-intestinal problem, cancer problem, heart problem, typhoid etc.. Medical reports of few patients are given in Fig. 5.1.3. The main problematic area was Achheja, Dujana, Sadopur and Badhpura village (Fig. 5.1.4). Many people of Sadopur village were suffering from various diseases. Survey reports and medical reports of patients interviewed, are included in Annexure.

People of the village have some stereotype. They were not ready to talk about cancer patient in their family. They didn't want to give any information about the cancer patient in their family. On the basis of discussion, one reason behind it was metrimonial problem. They thought it is a hereditary or communicable disease. No one wanted to start a family relation with cancer patient family. Few local residents Rame Nagar, Prof. Devedra Nagar and Advocate Surendra Baisoa helped me to findout cancer patients and their medical reports.

Many people were suffering from various health issues but due to the lack of awareness, they were not able to understand exact reason behind it. Results of current study revealed that consumption of contaminated water was one of the reason behind the occurrence of a large number of cancer patient at one place. People were not able to use pure water due to lack of awareness, finance and resources. During the survey, it was observed that few people took necessary steps to use the clean water and after longer run their health status improved.

Most of the people agreed that groundwater quality was not good. It had foul smell, turbidity and bad taste. Many of them uesd purification device to improve the quality of water. In their view, effluent of nearby industries were responsible for degradation of quality of groundwater. The response of majority of people of study area was that water quality was a major cause of carcinogenicity in large number of residents.

Fig. 5.1.1 Pictures of Survey conducted in Study area

गलगोटिया यूनिवर्सिटी की शोधकर्ता मीनू अग्रवाल ने जिला गौतमबुद्धनगर के गांव सादोपुर और अच्छेजा के निवासियों से मिलकर उनके पीने के पानी से संबंधित जानकारियां ली

फोकस आवाज,
संवाददाता

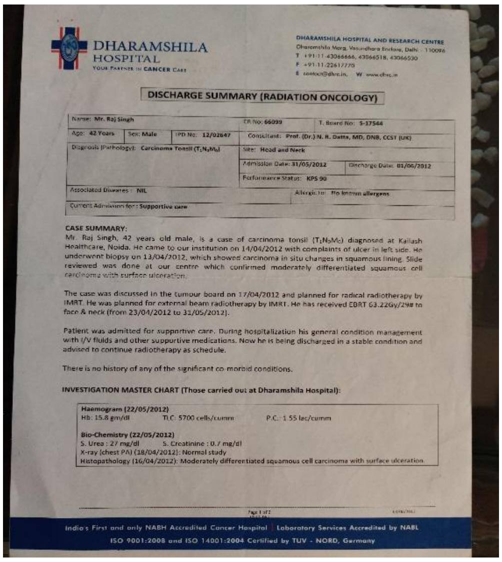
गौतमबुद्धनगर। गलगोटिया यूनिवर्सिटी की शोधकर्ता मीनू अग्रवाल ने जिला गौतम बुद्ध नगर के गांव सादोपुर और अच्छेजा के निवासियों से मिलकर उनके पीने के पानी से संबंधित जानकारियां ली दोनों गांव के रहने वाले कई व्यक्ति कैंसर जैसी गंभीर बीमारियों से पीड़ित हैं पीड़ित ज्यादातर बुजुर्ग हैं उनके शोध के अनुसार इन गांव के निवासियों में कैंसर का प्रमुख कारण वहां का दूषित भूजल है उन्होंने उन लोगों से मिलकर उनकी बीमारी के बारे में जाना और उन्हें इससे बचने के उपायों के बारे में जागरूक किया स्थानीय निवासी रामे नागर प्रोफेसर देवेन्द्र नागर और एडवोकेट सुरेंद्र बसोया ने इस अभियान में अपना योगदान दिया।

उद्धव ठाकरे

अयोध्या। (आरएनएस)

महाराष्ट्र के मुख्यमंत्री व शिवसेना प्रमुख उद्धव ठाकरे ने कहा है कि अयोध्या में राम मंदिर निर्माण के लिए बनाए गए ट्रस्ट को वह एक करोड़ रुपए का दान अपने ट्रस्ट की ओर से देंगे। उन्होंने कहा कि उत्तर प्रदेश सरकार अयोध्या में भूमि उपलब्ध कराए, इस भूमि पर आने वाले समय में महाराष्ट्र भवन का निर्माण कराया जाएगा। अयोध्या प्रवास के दौरान पंचशील सभागार में आयोजित पत्रकार वार्ता में शिवसेना प्रमुख व महाराष्ट्र के सीएम उद्धव ठाकरे नें व्यक्त किया। उन्होंने कहा कि यह मेरी तीसरी अयोध्या यात्रा है पहली बार 1918 में अयोध्या आया था। दूसरी बार जब मैं अयोध्या आया तो उस समय लोकसभा चुनाव होने वाले थे। हमनें कहा था कि केन्द्र में बैठी भाजपा सरकार कानून बनाकर

Fig. 5.1.2 Newspaper Report of the Survey (Source : Focus Aawaz, Gautam Budh Nagar)



DHARAMSHILA HOSPITAL
YOUR PARTNER IN CANCER CARE

DHARAMSHILA HOSPITAL AND RESEARCH CENTRE
Dharamshila Marg, Vasundhara Enclave, Delhi - 110096
T +91-11-43066666, 43066518, 43066530
F +91-11-22617770
E contact@dhrc.in, W www.dhrc.in

DISCHARGE SUMMARY (RADIATION ONCOLOGY)

Name: **Mr. Raj Singh**
CR No: **66099**
T. Board No: **S-17544**
Age: **42 Years**
Sex: **Male**
IPD No: **12/02647**
Consultant: **Prof. (Dr.) N. R. Datta, MD, DNB, CCST (UK)**
Diagnosis (Pathology): **Carcinoma Tonsil ($T_1N_3M_0$)**
Site: **Head and Neck**
Admission Date: **31/05/2012**
Discharge Date: **01/06/2012**
Performance Status: **KPS 90**
Associated Diseases : **NIL**
Allergic to: **No known allergens**
Current Admission for : **Supportive care**

CASE SUMMARY:
Mr. Raj Singh, 42 years old male, is a case of carcinoma tonsil ($T_1N_3M_0$) diagnosed at Kailash Healthcare, Noida. He came to our institution on 14/04/2012 with complaints of ulcer in left side. He underwent biopsy on 13/04/2012, which showed carcinoma in situ changes in squamous lining. Slide reviewed was done at our centre which confirmed moderately differentiated squamous cell carcinoma with surface ulceration.

The case was discussed in the tumour board on 17/04/2012 and planned for radical radiotherapy by IMRT. He was planned for external beam radiotherapy by IMRT. He has received EBRT 63.22Gy/29# to face & neck (from 23/04/2012 to 31/05/2012).

Patient was admitted for supportive care. During hospitalization his general condition management with I/V fluids and other supportive medications. Now he is being discharged in a stable condition and advised to continue radiotherapy as schedule.

There is no history of any of the significant co-morbid conditions.

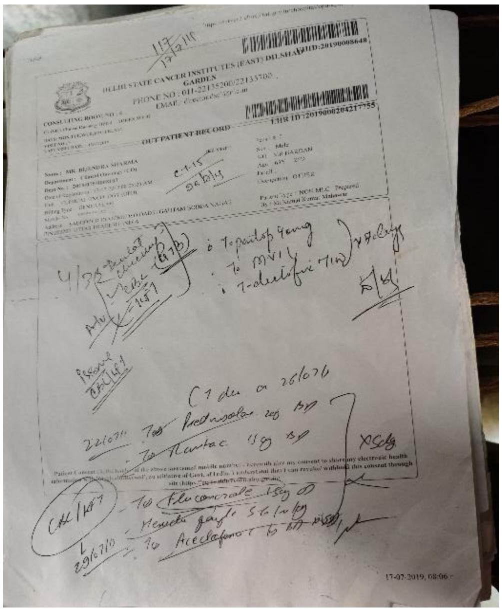
INVESTIGATION MASTER CHART (Those carried out at Dharamshila Hospital):

Haemogram (22/05/2012)
Hb: 15.8 gm/dl   TLC: 5700 cells/cumm   P.C.: 1.55 lac/cumm

Bio-Chemistry (22/05/2012)
S. Urea : 27 mg/dl   S. Creatinine : 0.7 mg/dl
X-ray (chest PA) (18/04/2012): Normal study
Histopathology (16/04/2012): Moderately differentiated squamous cell carcinoma with surface ulceration.

Page 1 of 2

India's First and only NABH Accredited Cancer Hospital | Laboratory Services Accredited by NABL
ISO 9001:2008 and ISO 14001:2004 Certified by TUV - NORD, Germany



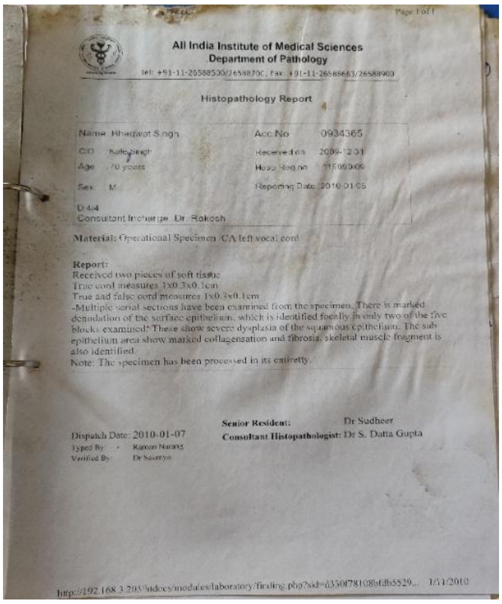
117/12/11

DELHI STATE CANCER INSTITUTES (EAST) DILSHAD GARDEN
PHONE NO : 011-22135200/22135700
UHID:20190008648

OUT PATIENT RECORD

Name : MR. BIJENDRA SHARMA
Sex : Male

17-07-2019, 08:06



Page 1 of 1

All India Institute of Medical Sciences
Department of Pathology
Tel: +91-11-26588500/26588700; Fax: +91-11-26588663/26588900

Histopathology Report

Name Bhagwat Singh
C/O Kale Singh
Age 70 years
Sex M
Acc No 0934365
Received on 2009-12-31
Hosp Reg no 115093/09
Reporting Date 2010-01-05
D 4/4
Consultant Incharge Dr. Rakesh

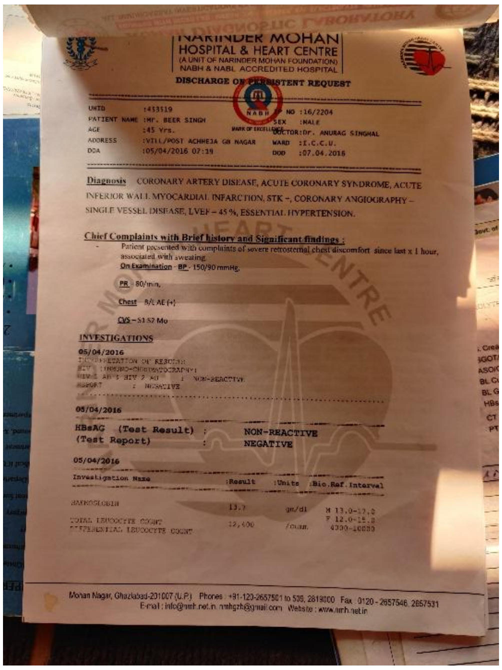
Material: Operational Specimen CA left vocal cord

Report:
Received two pieces of soft tissue
True cord measures 1x0.3x0.1cm
True and false cord measures 1x0.3x0.1cm
-Multiple serial sections have been examined from the specimen. There is marked denudation of the surface epithelium, which is identified focally in only two of the five blocks examined. These show severe dysplasia of the squamous epithelium. The sub epithelium area show marked collagensation and fibrosis, skeletal muscle fragment is also identified.
Note: The specimen has been processed in its entirety.

Senior Resident: Dr Sudheer
Consultant Histopathologist: Dr S. Datta Gupta

Dispatch Date: 2010-01-07
Typed By: Raman Narang
Verified By: Dr Saumya

http://192.168.3.203/hdocs/modules/laboratory/finding.php?sid=d330f78108bfdb5529... 1/11/2010



NARINDER MOHAN
HOSPITAL & HEART CENTRE
(A UNIT OF NARINDER MOHAN FOUNDATION)
NABH & NABL ACCREDITED HOSPITAL

DISCHARGE ON PERSISTENT REQUEST

UHID :453519
PATIENT NAME :Mr. BEER SINGH
AGE :45 Yrs.
ADDRESS :VILL/POST ACHHEJA GB NAGAR
DOA :05/04/2016 07:19
IP NO :16/2204
SEX :MALE
DOCTOR :Dr. ANURAG SINGHAL
WARD :I.C.C.U.
DOD :07.04.2016

Diagnosis CORONARY ARTERY DISEASE, ACUTE CORONARY SYNDROME, ACUTE INFERIOR WALL MYOCARDIAL INFARCTION, STK –, CORONARY ANGIOGRAPHY – SINGLE VESSEL DISEASE, LVEF – 45 %, ESSENTIAL HYPERTENSION.

Chief Complaints with Brief history and Significant findings :
- Patient presented with complaints of severe retrosternal chest discomfort since last x 1 hour, associated with sweating.
On Examination - BP - 150/90 mmHg,
PR - 80/min,
Chest B/L AE (+)
CVS – S1 S2 Mo

INVESTIGATIONS

05/04/2016
INTERPRETATION OF RESULTS
HIV (IMMUNO-CHROMATOGRAPHY)
HIV 1 AB & HIV 2 AB : NON-REACTIVE
REPORT : NEGATIVE

05/04/2016
HBsAG (Test Result) : NON-REACTIVE
(Test Report) : NEGATIVE

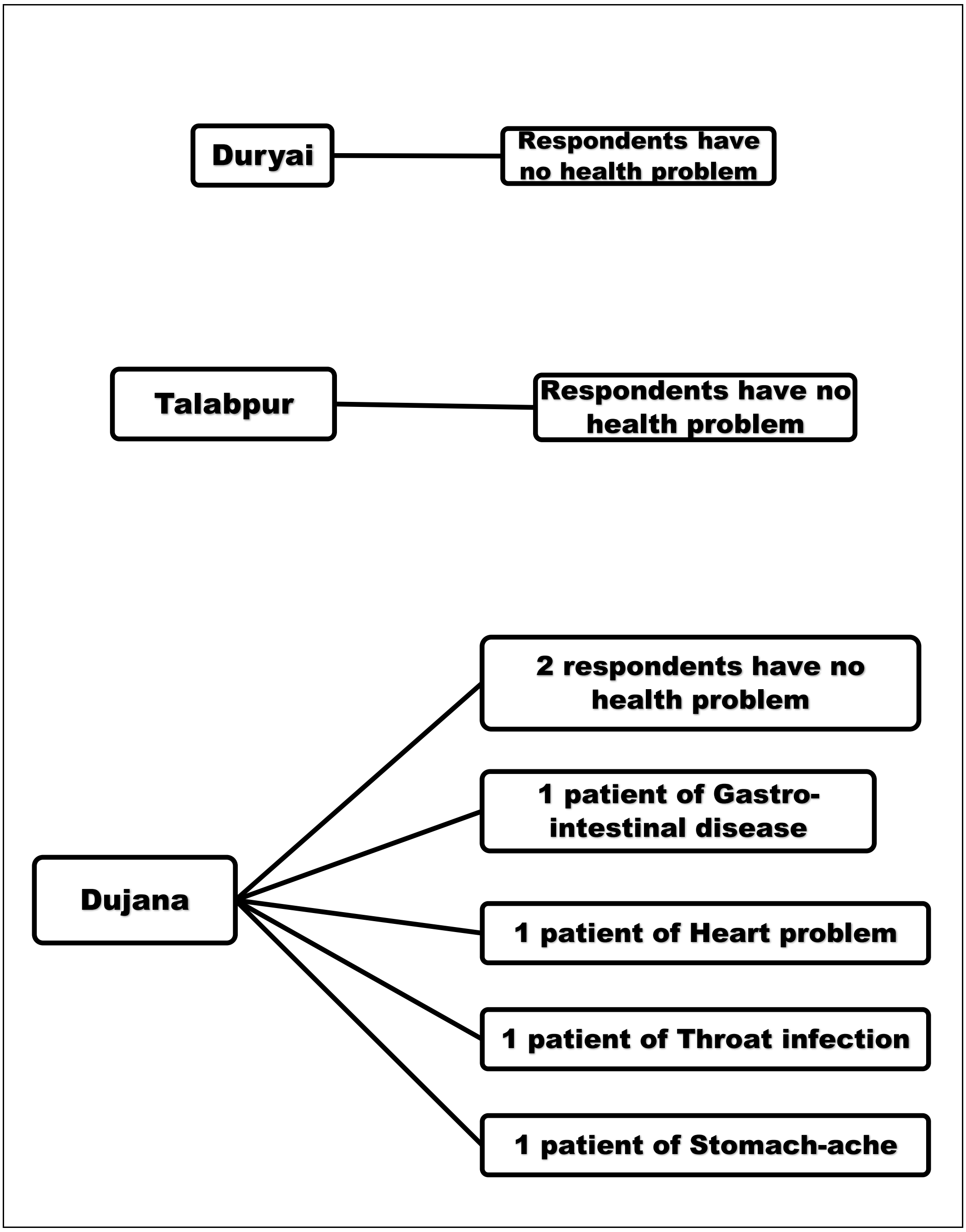
05/04/2016

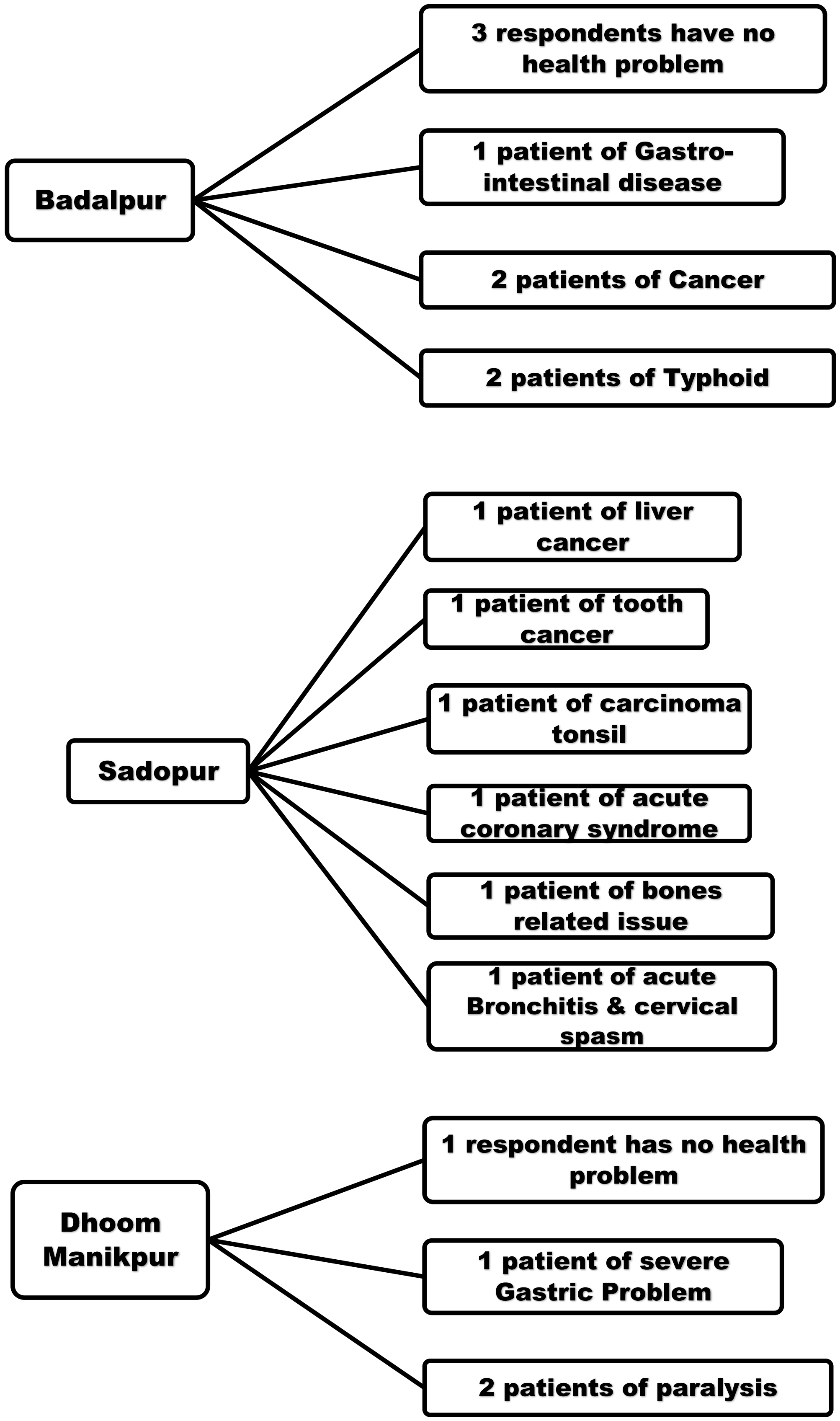
Investigation Name	Result	Units	Bio.Ref.Interval
HAEMOGLOBIN	13.7	gm/dl	M 13.0-17.0 F 12.0-15.0
TOTAL LEUCOCYTE COUNT	12,400	/cumm	4000-10000
DIFFERENTIAL LEUCOCYTE COUNT			

Mohan Nagar, Ghaziabad-201007 (U.P.) Phones : +91-120-2657501 to 509, 2819000 Fax : 0120 - 2657546, 2657531
E-mail : info@nmh.net.in, nmhgzb@gmail.com Website : www.nmh.net.in

Fig. 5.1.3 Medical reports of few Residents of study area

Health status of residents of study area based upon results of survey conducted is presented in Fig. 5.1.4. Pro forma of questionnaire is given in Fig. 4.2.




Badalpur
3 respondents have no health problem
1 patient of Gastro-intestinal disease
2 patients of Cancer
2 patients of Typhoid
Sadopur
1 patient of liver cancer
1 patient of tooth cancer
1 patient of carcinoma tonsil
1 patient of acute coronary syndrome
1 patient of bones related issue
1 patient of acute Bronchitis & cervical spasm
Dhoom Manikpur
1 respondent has no health problem
1 patient of severe Gastric Problem
2 patients of paralysis

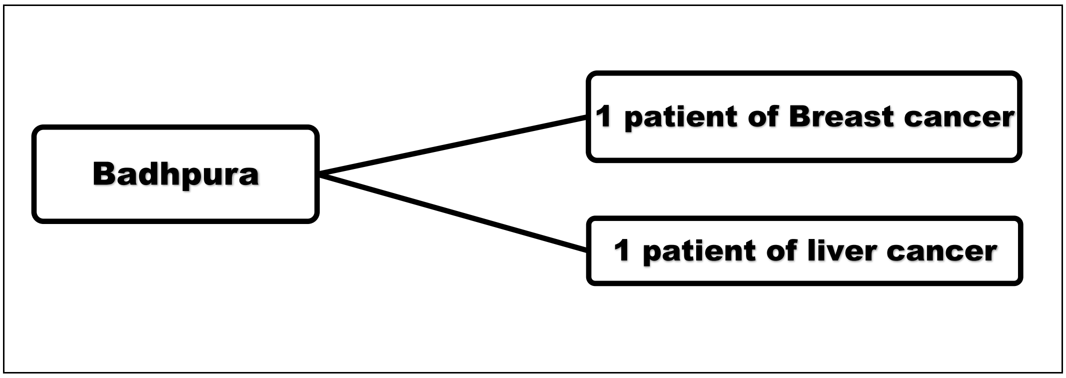


Fig. 5.1.4 Results of Survey conducted in Study area

Altogether twenty-two samples of groundwater were analysed in pre-monsoon and post-monsoon season of three consecutive years 2016, 2017 and 2018. The following parameters were analysed in all collected sample.

5.2.1 PHYSICO-CHEMICAL PARAMETERS

I. pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS) and Turbidity.

II. Cations: Total Hardness, Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+1}), Potassium (K^{+1}) and Boron (B^{+3}).

III. Anions: Total Alkalinity (CO_3^{-2} & HCO_3^{-1}), Chloride (Cl^{-1}), Fluoride (F^{-1}), Nitrite (NO_2^{-1}), Nitrate (NO_3^{-1}), Phosphate (PO_4^{-3}) and Sulphate (SO_4^{-2}).

IV. Ammonia (NH_3).

5.2.2 HEAVY METALS (Arsenic, Cadmium, Chromium, Copper, Nickel, Lead, Iron and Zinc).

PHYSICO-CHEMICAL PARAMETERS

5.2.1.1 Hydrogen Ion Concentration (pH)

The pH measures hydrogen ion concentration in natural water and specify the acidity or alkalinity. The chemical and biological characteristics of water are affected by acidity (or alkalinity) of it. pH is the resultant value of the interaction of organic content and minerals present in pure or slightly polluted water. The value of pH is determined mainly by the correlation between the concentration of free carbon dioxide, bicarbonates and carbonates. This correlation, in turn, depends substantially on the intensity of the process of photosynthesis and biochemical oxidation of organic substances, as well as on the chemical conversion of some mineral substance. Most of the natural waters have pH value greater than 7 due the presence of carbonates. Under natural conditions the pH value in groundwater ranges usually from 6.5 to 8.5. pH is affected by the increase in the content of colored humus substances. During the course of time, pH of water is affected by its exposure to air, change in temperature and biological activities. Drastic changes in pH of water also occur due to increased content of acids or alkalis discharged into the water bodies. pH also determines the fate of metals present in aquifers.

At alkaline pH, metal ions precipitate at the sediments (Chapman, 1996). Some natural organic compounds like humic and fulvic acids also control the pH of water. Many natural or anthropological activities disturb the natural acid-base balance of aquifers.

The pH trend in pre-monsoon and post-monsoon samples of study area in three consecutive years (2016-2018) is given in Table - 5.2.1.1 and 5.2.1.2.

The analytical results revealed that pH of groundwater of study area was neutral to alkaline in both the season but there was a slight decrease of pH in post-monsoon samples. During study period, analysed range of pH in groundwater samples was 7.09 to 9.15. pH value of studied samples ranged from 7.09 to 9.1 (in year 2016), 7.15 to 8.97 (in year 2017) and 7.17 to 9.15 (in year 2018).

To elucidate the quality of groundwater in different land use patterns, study area was divided into three zones–Agricultural zone, Industrial zone and Residential zone. In agricultural zone, pH value ranged from 7.12 to 7.98, in industrial zone its value ranged from 7.09 to 9.15 and in residential zone pH value was from 7.20 to 8.01. The minimum pH value of 7.09 was recorded in water sample collected from the water quality station of Khera Dharampura in post-monsoon season of 2016. The highest pH value of 9.15 was recorded in water sample collected from the water quality station of Dujana in pre-monsoon season of 2018.

Groundwater of study area showed dilution due to monsoon and lesser alkalinity was observed in post-monsoon samples due the recharge of ground aquifers. The impact of monsoon on pH was greater in year 2018 due to more influx of rain water. The results of analysis also revealed that post-monsoon samples of water quality station of Khera Dharampura had a rise in pH. The increase in pH of groundwater showed that dissolution of ions has been enhanced in rainy season due to more soil – water interaction in this area.

Table - 5.2.1.1 Seasonal Variation in pH of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	7.38	7.42	7.86	3.50%	0.90%	7.90%
			Post-monsoon	7.12	7.35	7.24			
	S2	Duryai	Pre-monsoon	7.91	7.82	7.88	3.00%	8.60%	5.30%
			Post-monsoon	7.67	7.15	7.46			
	S3	Duryai	Pre-monsoon	7.64	7.67	7.79	6.80%	3.80%	5.10%
			Post-monsoon	7.12	7.38	7.39			
	S4	Talabpur	Pre-monsoon	7.69	7.59	7.98	3.40%	2.20%	6.50%
			Post-monsoon	7.43	7.42	7.46			
Industrial	S5	Bisrakh Road	Pre-monsoon	7.68	7.75	7.48	1.60%	6.50%	3.60%
			Post-monsoon	7.56	7.25	7.21			
	S6	Bisrakh Road	Pre-monsoon	8.13	7.56	7.49	4.20%	3.70%	4.30%
			Post-monsoon	7.79	7.28	7.17			
	S7	Bisrakh Road	Pre-monsoon	8.24	8.04	8.56	0.70%	0.40%	3.30%
			Post-monsoon	8.18	8.01	8.28			
	S8	Bisrakh Road	Pre-monsoon	7.95	7.82	7.75	5.70%	2.20%	5.20%
			Post-monsoon	7.5	7.65	7.35			
	S9	Bisrakh Road	Pre-monsoon	7.34	7.56	8.02	1.60%	1.30%	4.60%
			Post-monsoon	7.22	7.46	7.65			
	S10	Khera Dharampura	Pre-monsoon	7.27	7.37	7.45	2.50%	3.00%	2.30%
			Post-monsoon	7.09	7.15	7.28			
	S11	Bishnuli	Pre-monsoon	7.81	7.61	7.8	6.50%	2.40%	5.50%
			Post-monsoon	7.3	7.43	7.37			
	S12	Achheja	Pre-monsoon	7.93	8.1	7.51	1.50%	3.30%	1.70%
			Post-monsoon	7.81	7.83	7.38			
	S13	Achheja	Pre-monsoon	7.79	7.89	7.34	1.80%	1.30%	1.80%
			Post-monsoon	7.65	7.79	7.21			
	S14	Dujana	Pre-monsoon	8.1	7.84	8.04	2.50%	2.30%	3.00%
			Post-monsoon	7.9	7.66	7.8			
	S15	Dujana	Pre-monsoon	9.1	8.97	9.15	3.30%	2.60%	1.60%
			Post-monsoon	8.8	8.74	9			
	S16	Dujana	Pre-monsoon	8.77	8.58	8.5	4.80%	4.70%	2.40%
			Post-monsoon	8.35	8.18	8.3			
	S17	Dujana	Pre-monsoon	8.66	8.56	8.9	3.00%	2.10%	7.90%
			Post-monsoon	8.4	8.38	8.2			
	S18	Badalpur	Pre-monsoon	8.65	8.51	8.85	2.90%	2.40%	8.50%
			Post-monsoon	8.4	8.31	8.1			
Residential	S19	Sadopur	Pre-monsoon	7.97	7.87	8.01	9.50%	4.10%	5.60%
			Post-monsoon	7.21	7.55	7.56			
	S20	Dairy Maccha	Pre-monsoon	7.79	7.84	7.97	1.40%	0.90%	9.30%
			Post-monsoon	7.68	7.77	7.23			
	S21	Dhoom Manikpur	Pre-monsoon	7.65	7.74	7.43	-0.90%	-1.00%	-1.70%
			Post-monsoon	7.72	7.82	7.56			
	S22	Badhpura	Pre-monsoon	7.7	7.31	7.8	3.20%	1.50%	7.10%
			Post-monsoon	7.45	7.2	7.25			

Table - 5.2.1.2 Statistical Summary of pH in Groundwater samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	7.27	Khera Dharampura	7.09	Khera Dharampura	7.31	Badhpura	7.15	Khera Dharampura, Duryai	7.34	Achheja	7.17	Bisrakh Road
Max.	9.1	Dujana	8.8	Dujana	8.97	Dujana	8.74	Dujana	9.15	Dujana	9	Dujana
Mean	7.96		7.70		7.88		7.67		7.98		7.61	
St. Dev.	0.48		0.48		0.43		0.43		0.51		0.48	

The empirical probability distribution plot or histogram of pH value of groundwater samples during three consecutive study year (2016, 2017 & 2018) is given in Fig. 5.2.1.1, 5.2.1.2 and 5.2.1.3 respectively. Plot showed that majority of samples fall in middle of curve in year 2016 & 2017 and hence have suitable value of pH. In year 2018, majority of samples were located on the left side of curve showing acidic nature of water samples. Box and Whisker plot was also drawn to know the distributional characterstics of pH values of groundwater during study period (Fig. 5.2.1.4). In year 2016, only one outlier was present. In year 2017 and 2018, two outliers were present. Throughout the study period, the data was symmetrical, but in year 2017, it was tightly grouped. Median value was slightly lesser than mean value in each year. Fig. 5.2.1.5 showed the spatial distribution of pH of groundwater in study area. Distribution pattern of pH showed that groundwater of central and north-east part of study area had high pH value.

However pH of drinking water does not have any adverse health effect but it is a distinct operative parameter for water quality (WHO 2017). The pH of water should be controlled to reduce the corrosion in water distribution network. The corrosion of water distribution pipes adversely affects the taste & appearance of water. It also causes metal contamination of water. The extreme high or low value of pH in supplied water is due to any breakage in lining of Cement-mortar lined ductile iron pipe. BIS and WHO give a standard range of 6.5 - 8.5 for drinking water. There is no permissible limit of pH for drinking water. The analytical results showed that nearly 11% of samples were out of the standard range of drinking water. These samples were collected from the water quality stations of Dujana, Badalpur and bisrakh road. All of these stations were in industrial zone of study area hence reflects the leaching of chemicals from industrial effluents to ground aquifers. Rest of the water quality stations of study area have suitable quality of drinking water.

Singh & Tripathi, (2016) studied ground water quality of Noida region of National Capital Region of India, and reported that pH of ground water ranged from 7.1 to 7.9. Similar type of studies were done by many researchers (Madhnure et al., (2007) in Pandharkawada area, Yavakmal district, Maharashtra; Vasanthavigar et al., (2010) in Tamilnadu; Salifu et al., (2017) in Wa-Lawra Gold belt of Ghana). The major sources of alkaline pH of water are anthropogenic actions, industries and slag dumps (Roadcap et al., 2005; Mulamattathil et al., 2015; Gaikwad et al., 2019).

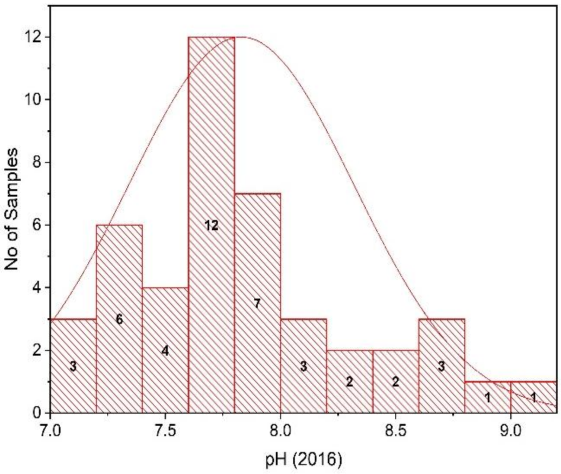


Fig. 5.2.1.1 Empirical probability distribution of pH in Groundwater samples (in year 2016)

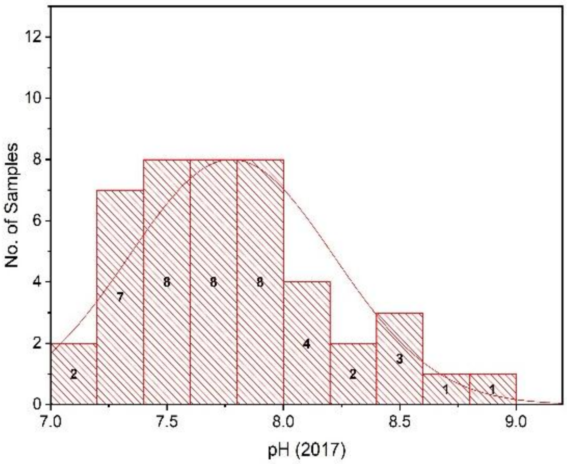


Fig. 5.2.1.2 Empirical probability distribution of pH in Groundwater samples (in year 2017)

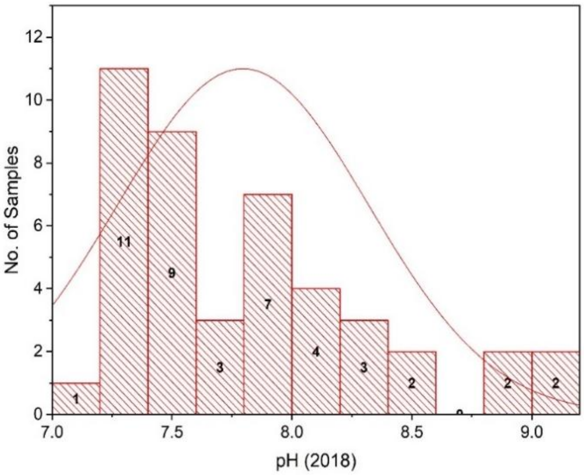


Fig. 5.2.1.3 Empirical probability distribution of pH in Groundwater samples (in year 2018)

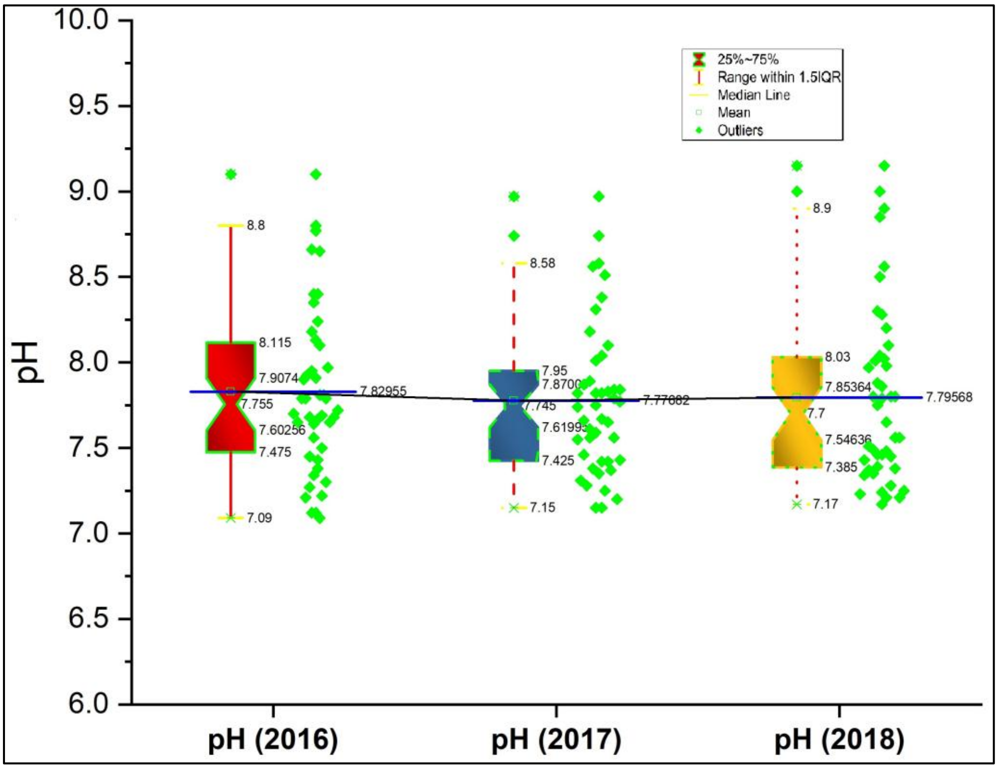
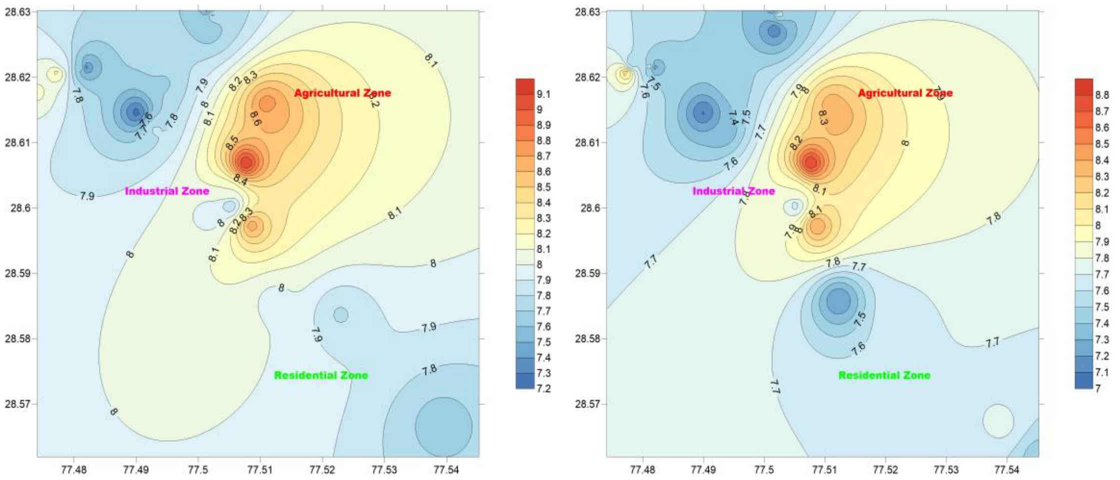
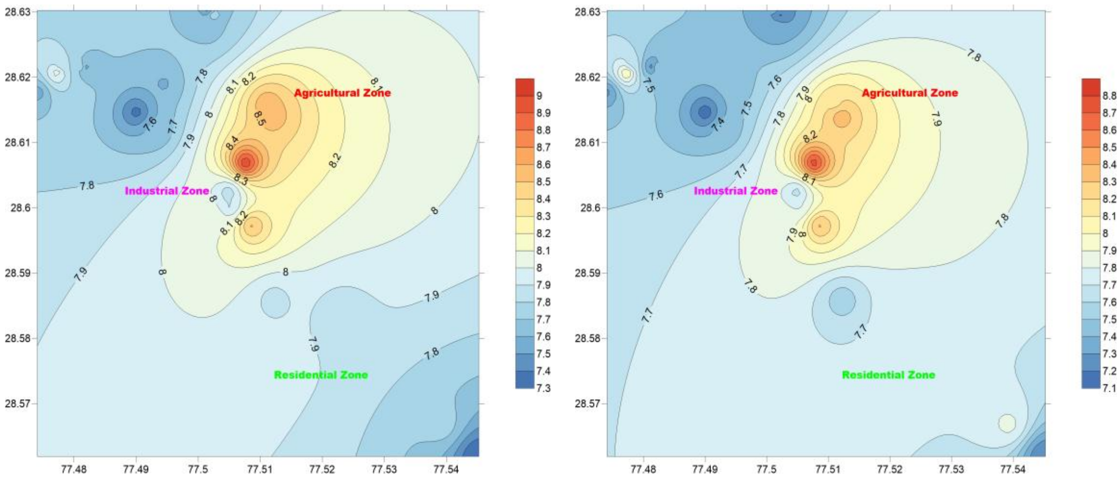


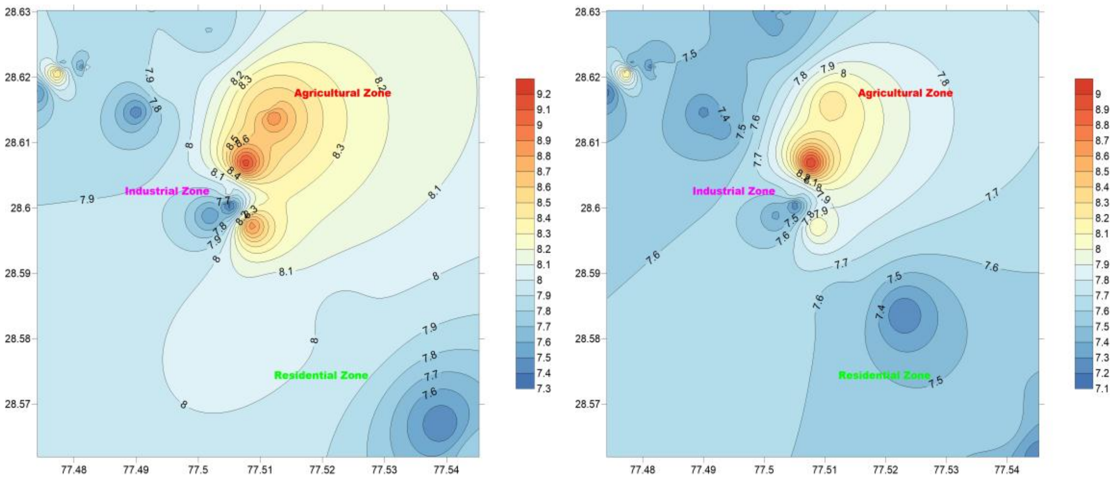
Fig. 5.2.1.4 Box and Whisker plot of pH in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.5 Spatial distribution of pH in Groundwater samples during study period (2016-2018)

5.1.1.2 Electrical Conductivity (EC)

Electrical conductivity measures the capability of an aqueous solution to conduct electricity. Flow of electric-current is caused by the ions present in water. Electrical conductivity only measures the ionic species quantitatively not qualitatively. Conductivity of water does not measure the quantity of non-electrolyte present in it. Conductivity depends on the quantity, mobility and valency of ions. The temperature of the water also regulates conductivity. Conductivity increase with the increase in temperature of water and changes at the rate of 2% per degree centigrade but may not vary significantly in the flowing water. Inorganic substacnes show better conductance while organic compounds are poor current conductors, as they do not dissociate into ions. Hence electrical conductivity denotes the presence of inorganic pollutants and its value represents the cumulative concentration of these pollutants.

Table - 5.2.1.3 and 5.2.1.4 are representing the electrical Conductivity trends in study area.

There is a wide variation in EC value of groundwater in study area. During 2016, EC value of groundwater was from 682 to 4251 µmhos/cm, in 2017 its value varied from 520 to 2648 µmhos/cm while in 2018 EC value was from 607 to 3448 µmhos/cm.

In agricultural zone, EC value ranged from 727 to 1529 µmhos/cm with a mean value of 995 µmhos/cm. The EC value in industrial zone ranged between 520 and 4251 µmhos/cm providing a mean value of 1748 µmhos/cm. Residential zone of study area also has a wide range of conductivity with a minimum value of 561 µmhos/cm and a maximum value of 2800 µmhos/cm with a mean of 1443 µmhos/cm. The decreasing order of mean value of EC in different zone are; industrial zone (1748 µmhos/cm) > residential zone (1443 µmhos/cm) > agricultural zone (995 µmhos/cm).

Table - 5.2.1.3 Seasonal Variation in EC (µmhos/cm) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	1525	1059	1529	7.50%	-6.70%	12.40%
			Post-monsoon	1410	1130	1340			
	S2	Duryai	Pre-monsoon	939	845	949	7.50%	-3.80%	12.00%
			Post-monsoon	869	877	835			
	S3	Duryai	Pre-monsoon	860	727	871	7.40%	-9.40%	11.70%
			Post-monsoon	796	795	769			
	S4	Talabpur	Pre-monsoon	910	765	1270	3.00%	-3.30%	11.20%
			Post-monsoon	883	790	1128			
Industrial	S5	Bisrakh Road	Pre-monsoon	710	633	695	1.70%	-3.90%	12.70%
			Post-monsoon	698	658	607			
	S6	Bisrakh Road	Pre-monsoon	2371	1810	2617	4.70%	-16.90%	10.30%
			Post-monsoon	2260	2115	2348			
	S7	Bisrakh Road	Pre-monsoon	2107	1657	1900	2.70%	-7.40%	12.60%
			Post-monsoon	2050	1779	1660			
	S8	Bisrakh Road	Pre-monsoon	917	819	898	1.60%	1.00%	11.20%
			Post-monsoon	902	811	797			
	S9	Bisrakh Road	Pre-monsoon	780	615	790	0.60%	-14.80%	11.40%
			Post-monsoon	775	706	700			
	S10	Khera Dharampura	Pre-monsoon	1292	1007	1401	11.10%	-4.50%	13.60%
			Post-monsoon	1149	1052	1210			
	S11	Bishnuli	Pre-monsoon	1283	1153	1179	6.90%	1.60%	10.90%
			Post-monsoon	1195	1135	1051			
	S12	Achheja	Pre-monsoon	4251	1878	2758	4.50%	-33.20%	2.10%
			Post-monsoon	4061	2501	2700			
	S13	Achheja	Pre-monsoon	2330	1650	2298	3.30%	-17.50%	11.30%
			Post-monsoon	2252	1939	2038			
	S14	Dujana	Pre-monsoon	760	538	943	10.30%	3.30%	6.80%
			Post-monsoon	682	520	879			
	S15	Dujana	Pre-monsoon	2990	1818	2638	9.20%	-21.00%	11.90%
			Post-monsoon	2715	2200	2325			
	S16	Dujana	Pre-monsoon	2845	2102	3448	2.90%	-26.00%	13.30%
			Post-monsoon	2763	2648	2990			
	S17	Dujana	Pre-monsoon	2365	1790	2441	2.60%	-23.50%	13.00%
			Post-monsoon	2304	2211	2124			
	S18	Badalpur	Pre-monsoon	2580	1980	2868	4.10%	-20.20%	11.00%
			Post-monsoon	2475	2380	2553			
Residential	S19	Sadopur	Pre-monsoon	765	561	660	0.70%	-8.70%	6.80%
			Post-monsoon	760	610	615			
	S20	Dairy Maccha	Pre-monsoon	890	1222	1491	6.60%	-8.70%	11.50%
			Post-monsoon	831	1328	1320			
	S21	Dhoom Manikpur	Pre-monsoon	1600	1923	2055	10.10%	9.80%	14.70%
			Post-monsoon	1438	1735	1753			
	S22	Badhpura	Pre-monsoon	2800	1763	2310	21.30%	-4.90%	6.90%
			Post-monsoon	2205	1850	2150			

Table - 5.2.1.4 Statistical Summary of EC (µmhos/cm) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	710	Bisrakh Road	682	Dujana	538	Dujana	520	Dujana	660	Sadopur	607	Bisrakh Road
Max.	4251	Achheja	4061	Achheja	2102	Dujana	2648	Dujana	3448	Dujana	2990	Dujana
Mean	1721.4		1612.4		1287.0		1444.1		1727.7		1540.5	
St. Dev.	977.25		915.09		548.70		700.47		836.48		752.22	

It was observed from the analytical results of pre-monsoon and post-monsoon samples that EC of groundwater decreased after rainy season. Lesser conductivity in post-monsoon season reflects that ionic strength of groundwater decreased after precipitation. Rainfall has recharged the ground aquifers and recharging of groundwater reduced the ionic concentration of water. Although there was overall decrease in conductivity of water at all water quality station in post-monsoon season but water quality station at Dujana showed increase of conductivity (from 2102 to 2648 µmhos/cm) after monsoon during 2017. The rise in ionic concentration at Dujana water quality station was due to industrial pollution from various manufacturing units in this area like iron & steel industry, rice mill etc. Electrical conductivity depicts the strength of cations and anions in water and hence its high value makes the water unfit for drinking purpose.

During the study period, distribution plot of EC of groundwater samples showed that comparatively lesser number of samples were present on the right side of plot (Fig. 5.2.1.6, 5.2.1.7 & 5.2.1.8). This explained that although maximum value of EC of groundwater was high throughout the study period but number of samples having high EC value was not very big. Box and whisker plot of electrical conductivity value of groundwater in three consecutive years showed that all the values were within the box and whisker, no outliers were present in it (Fig. 5.2.1.9). Large variation was observed between the median and mean value. Mean value of EC was considerably higher than median value. Spatial distribution graph of EC value of groundwater samples in study area during thoughout study period is given in Fig. 5.2.1.10. In year 2016, groundwater of central part of study area (industrial & agricultural) had high value of

EC. Overall EC value of groundwater decreased in year 2017 & 2018 but central part remained polluted.

Ibraheem et al., (2015) reported that electrical conductivity has direct correlation with the total dissolved solids value of water. High range of electrical conductivity (673 µS to 3470 µS) was found in groundwater of Hyderabad (Jampani et al., 2018). Very high range of electrical conductivity was reported by Vasanthavigar et al., (2010); Ravikumar et al., (2011); Ackah et al., (2011) in different study areas.

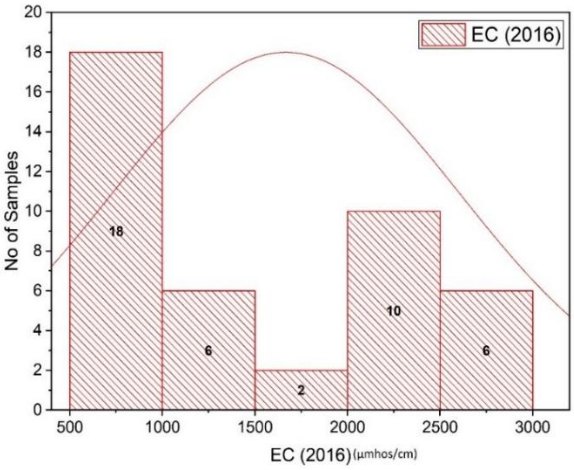


Fig. 5.2.1.6 Empirical probability distribution of EC in Groundwater samples (in year 2016)

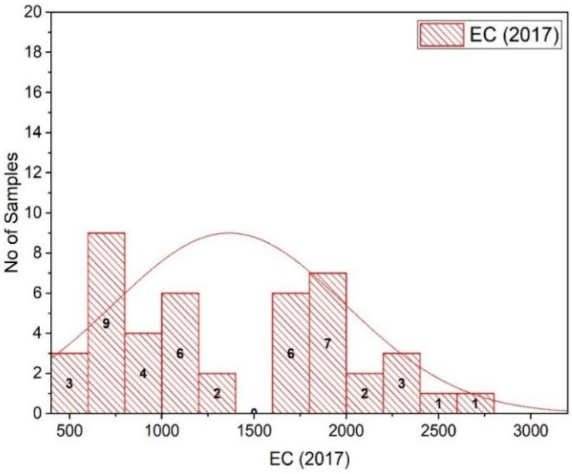


Fig. 5.2.1.7 Empirical probability distribution of EC in Groundwater samples (in year 2017)

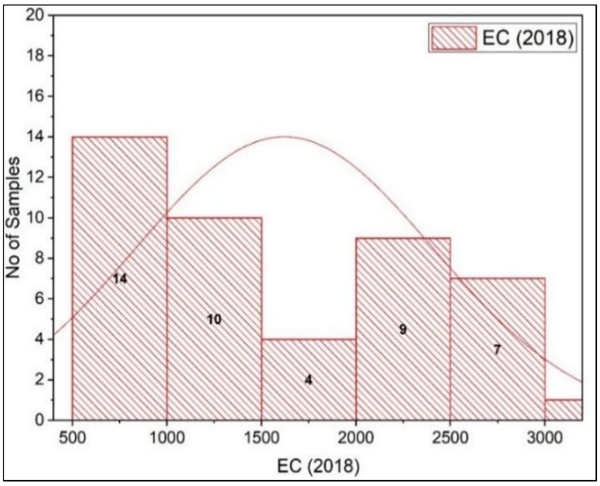


Fig. 5.2.1.8 Empirical probability distribution of EC in Groundwater samples (in year 2018)

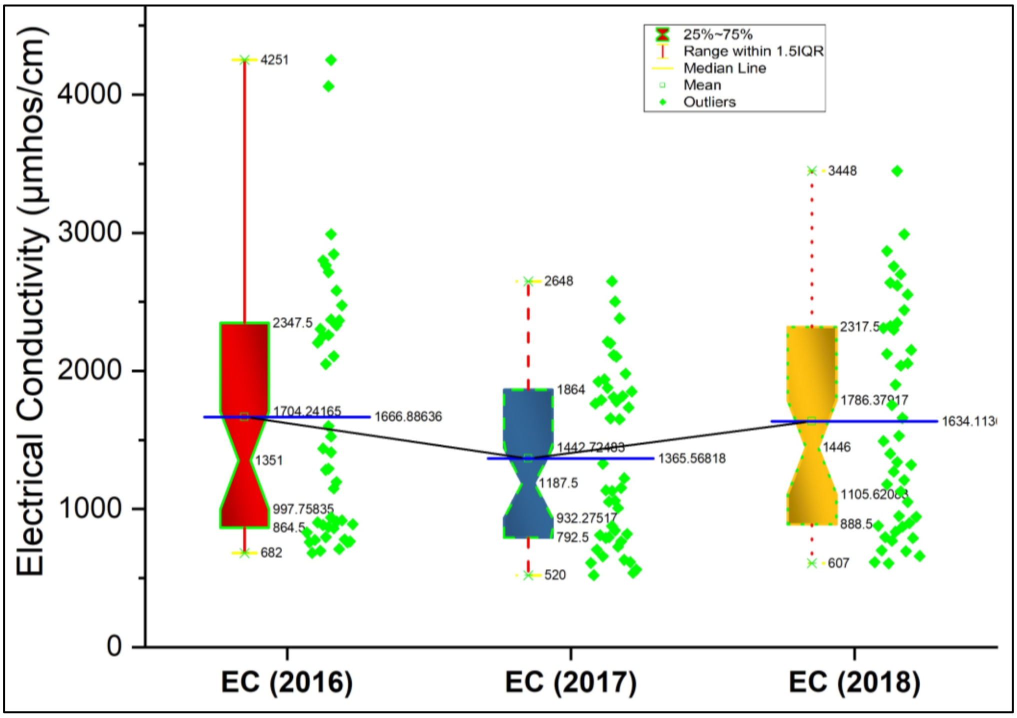
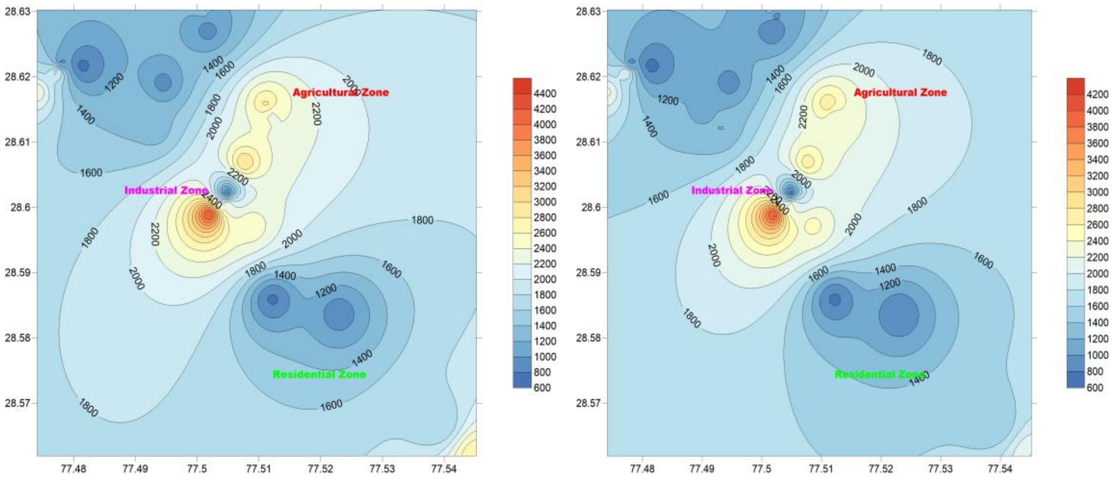
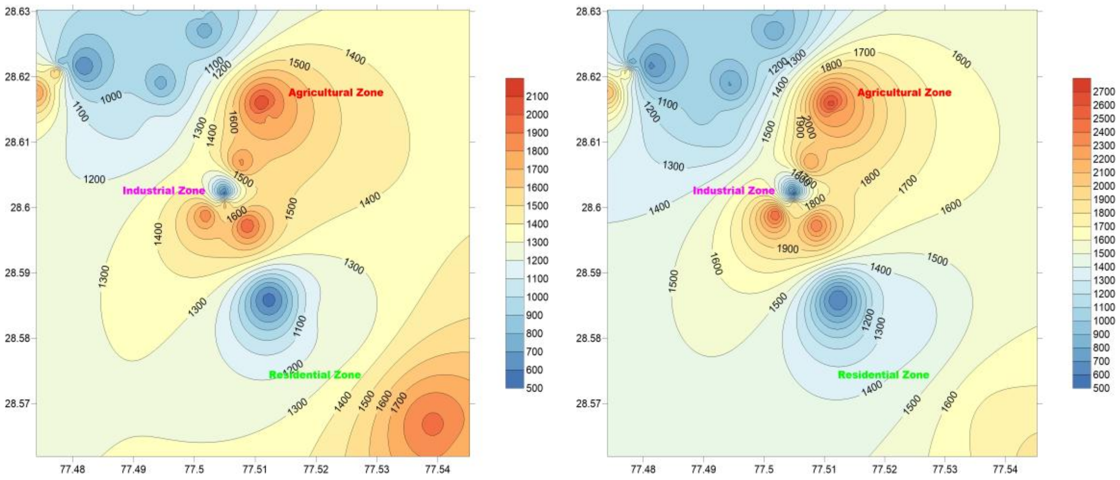


Fig. 5.2.1.9 Box and Whisker plot of EC in Groundwater samples during study period (2016-2018)



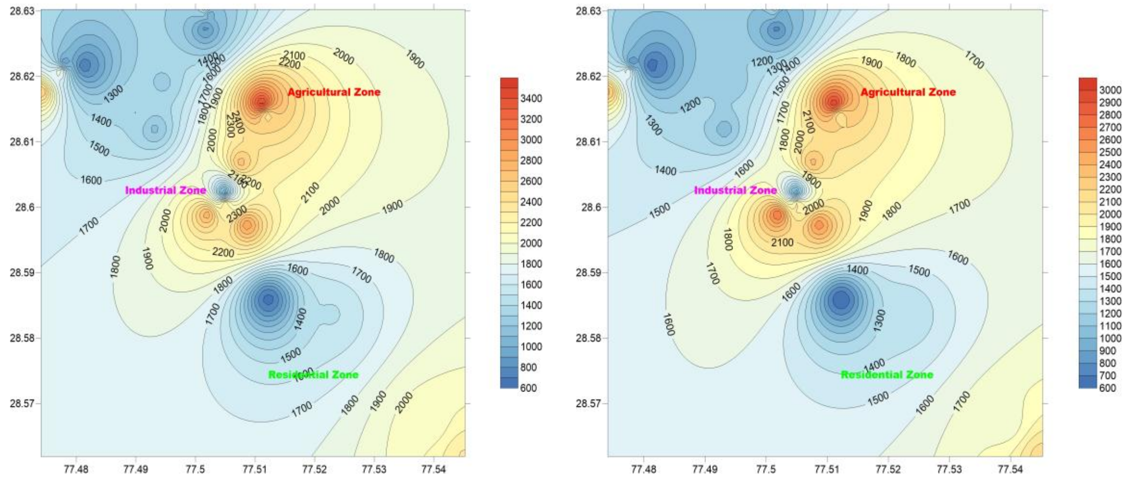
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.10 Spatial distribution of EC in Groundwater samples of study area during study period (2016-2018)

5.1.1.3 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) measures the quantity of mineral and salts present in water. TDS represents various kinds of nutrients and has been proved to be a very useful parameter for the characterization of quality of water for drinking purpose. The leading inorganic constituents of natural water are carbonate, bicarbonate, fluoride, chloride and sulphate of calcium, magnesium, sodium and potassium. Nitrate is also found in natural water of agricultural prone areas. The potability of water depends upon the TDS value of it. The drinking water with very high TDS (metallic taste) or low TDS (insipid taste) is unacceptable. Presence of TDS in excess may disturb the ecological balance and cause imbalance in osmotic regulation and suffocation in aquatic fauna even if fair amount of dissolved oxygen is present. If any one of the dissolved inorganic salts becomes excessive, the water becomes unfit for drinking purpose and its use for a substantial period for irrigation causes salinity of soil. TDS enriches the nutrient status of water and in higher quantity it results in eutrophication of the aquatic ecosystem. Sudden increase in TDS can often indicate pollution by an extreaneous source. Harmful and lethal heavy metals are also found in the form of dissolved solids.

The Total dissolved solids in pre-monsoon and a post-monsoon groundwater samples of study area in three consecutive years (2016-2018) is given in Table - 5.2.1.5 and 5.2.1.6.

TDS of studied samples, in study area, varied from 339 mg/L (at Dujana water quality station in post-monsoon samples of year 2017) to 2764 mg/L (at Achheja water quality station in pre-monsoon samples of year 2016). Analytical results revealed that one water quality station S6 at Achheja had TDS value (2764 mg/L in pre-monsoon & 2641 mg/L in post-monsoon) nearly two times of the other water quality station S5 in the same village (1516 mg/L in pre-monsoon & 1465 mg/L in post-monsoon). This exceptional increase in TDS value showed infiltration of inorganic and organic substances at particular place. Water quality stations at Bisrakh road also had high TDS value of groundwater. This area came under industrial zone and several big or small manufacturing units were present in this area. The effluents of these industries were dumped directly into surface water or groundwater without any treatment,, which enhanced the TDS level of groundwater in this area.

Table - 5.2.1.5 Seasonal variation in TDS (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	992	688	995	7.50%	-7.00%	12.40%
			Post-monsoon	918	736	872			
	S2	Duryai	Pre-monsoon	611	549	618	7.40%	-3.60%	12.00%
			Post-monsoon	566	569	544			
	S3	Duryai	Pre-monsoon	560	472	565	7.90%	-9.50%	11.30%
			Post-monsoon	516	517	501			
	S4	Talabpur	Pre-monsoon	590	497	825	2.50%	-3.60%	11.30%
			Post-monsoon	575	515	732			
Industrial	S5	Bisrakh Road	Pre-monsoon	460	411	453	1.10%	-4.40%	13.20%
			Post-monsoon	455	429	393			
	S6	Bisrakh Road	Pre-monsoon	1540	1177	1700	4.50%	-16.90%	10.30%
			Post-monsoon	1470	1376	1525			
	S7	Bisrakh Road	Pre-monsoon	1369	1077	1236	2.60%	-7.20%	12.60%
			Post-monsoon	1334	1155	1080			
	S8	Bisrakh Road	Pre-monsoon	595	532	585	1.50%	1.10%	11.30%
			Post-monsoon	586	526	519			
	S9	Bisrakh Road	Pre-monsoon	509	400	512	0.80%	-15.00%	11.30%
			Post-monsoon	505	460	454			
	S10	Khera Dharampura	Pre-monsoon	841	655	912	11.30%	-4.10%	13.60%
			Post-monsoon	746	682	788			
	S11	Bishnuli	Pre-monsoon	835	749	765	7.20%	1.30%	10.80%
			Post-monsoon	775	739	682			
	S12	Achheja	Pre-monsoon	2764	1221	1794	4.50%	-33.00%	2.10%
			Post-monsoon	2641	1624	1756			
	S13	Achheja	Pre-monsoon	1516	1073	1492	3.40%	-17.50%	11.30%
			Post-monsoon	1465	1261	1323			
	S14	Dujana	Pre-monsoon	495	350	614	10.30%	3.10%	7.20%
			Post-monsoon	444	339	570			
	S15	Dujana	Pre-monsoon	1945	1182	1716	9.30%	-21.10%	12.00%
			Post-monsoon	1764	1431	1510			
	S16	Dujana	Pre-monsoon	1848	1366	2240	2.80%	-25.90%	13.20%
			Post-monsoon	1797	1720	1945			
	S17	Dujana	Pre-monsoon	1536	1164	1586	2.40%	-23.50%	12.90%
			Post-monsoon	1499	1438	1382			
	S18	Badalpur	Pre-monsoon	1678	1287	1865	4.10%	-20.10%	10.90%
			Post-monsoon	1610	1546	1661			
Residential	S19	Sadopur	Pre-monsoon	498	365	430	0.40%	-8.20%	6.70%
			Post-monsoon	496	395	401			
	S20	Dairy Maccha	Pre-monsoon	580	794.3	970	7.10%	-8.80%	11.40%
			Post-monsoon	539	864	859			
	S21	Dhoom Manikpur	Pre-monsoon	1012	1250	1361	15.10%	9.90%	17.40%
			Post-monsoon	859	1126	1124			
	S22	Badhpura	Pre-monsoon	1820	1146	1498	21.40%	-5.10%	6.60%
			Post-monsoon	1431	1204	1399			

Table - 5.2.1.6 Statistical Summary of TDS (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	460	Bisrakh Road	444	Dujana	350	Dujana	339	Dujana	430	Sadopur	393	Bisrakh Road
Max.	2764	Achheja	2641	Achheja	1366	Dujana	1720	Dujana	2240	Dujana	1945	Dujana
Mean	1117.91		1045.0		836.60		938.73		1124.2		1000.9	
St. Dev.	635.36		595.89		356.75		455.07		543.9		488.98	

The results of study also showed that most of the samples had lesser dissolved solids in post-monsoon season. But during year 2017, the amount of dissolved solids increased after rainfall. However water quality stations at Achheja, Bisrakh road, Dujana and Badalpur (S5, S6, S9, S12, S19, S20, S21 and S22) showed significant increase (>15%) in TDS value. During the study period, lesser precipitation in year 2017 as compared to other years, caused this type of trend in study area.

The empirical probability distribution plots of TDS in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.1.11, 5.2.1.12 and 5.2.1.13 respectively. Investigation of the probability distribution of dataset revealed that a large number of studied samples were around TDS value of 500 mg/L. Box and Whisker plot was also drawn to know the distributional characterstics of TDS values of groundwater during study period (Fig. 5.2.1.14). In year 2016, maximum variability in data was observed. Plot depicts that mean and median value of TDS lowered in year 2017 and again increased in year 2018. The 25th and 75th percentile of TDS in year 2016, 2017 & 2018 were 563, 516, 577.5 and 1526, 1212.5, 1504 respectively. Spatial distribution or GIS map of TDS of groundwater in study area is given in Fig. 5.2.1.15. In year 2016, TDS of groundwater in industrial zone was very high. But in year 2017 & 2018, TDS of groundwater was high in both industrial and agricultural zone.

BIS gives 500 mg/L as the acceptable limit and 2000 mg/L as permissible limit of TDS in drinking water. WHO does not give a health based guideline value for TDS but drinking water with TDS lesser than 600 mg/L is good for drinking and TDS greater than 1000 mg/L in drinking water changes the potability of water. Out of total analysed samples, 83% of samples crossed the acceptable limit and 3 samples were beyond the permissible limit of BIS for TDS in drinking water. The samples which had higher TDS value belongs to water quality station at Achheja and Dujana. Nearly 55% of samples were below the prescribed range of TDS in drinking water by WHO. Srinivas et al., (2002) in Andhra Pradesh reported TDS from 270 mg/L to 2364 mg/L. Ranjana, (2010) analysed TDS ranging from 700 mg/L to 3200 mg/L in groundwater of Kotputli Town, Jaipur, Rajasthan. Singh & Hussian, (2016) analysed the groundwater of Greater Noida sub-basin of Uttar Pradesh and reported that all the analysed samples except one (having TDS 2182 mg/L) were below the permissible limit of TDS given by BIS. Drinking water with high TDS is objectionable in taste and causes gastrointestinal irritation (Ahamed et al., 2017). Jampani et al., (2018) reported the range of 430 mg/L to 2221 mg/L in ground water of Hyderabad.

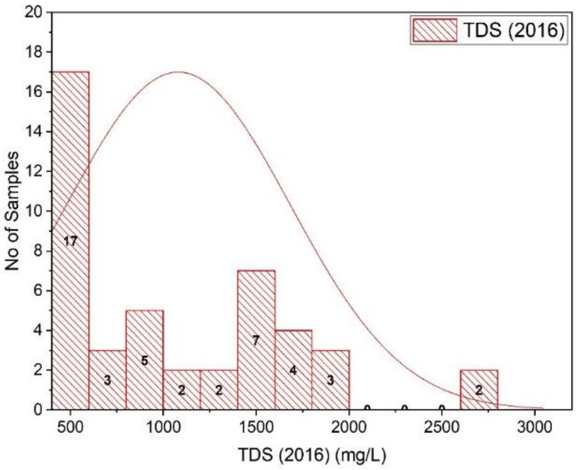


Fig. 5.2.1.11 Empirical probability distribution of TDS in Groundwater samples (in year 2016)

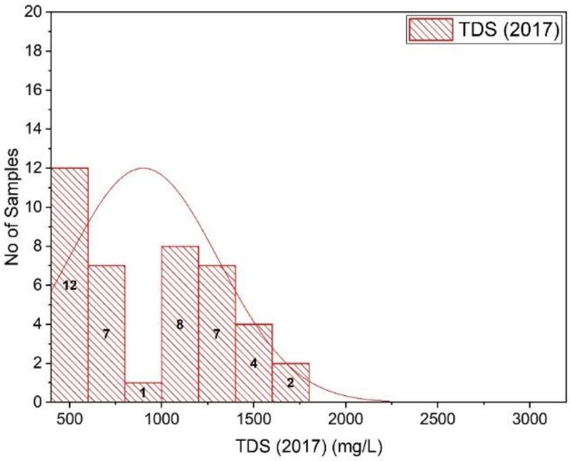


Fig. 5.2.1.12 Empirical probability distribution of TDS in Groundwater samples (in year 2017)

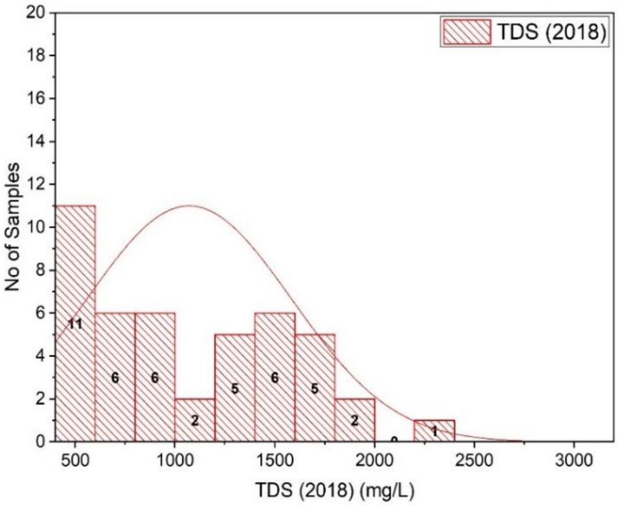


Fig. 5.2.1.13 Empirical probability distribution of TDS in Groundwater samples (in year 2018)

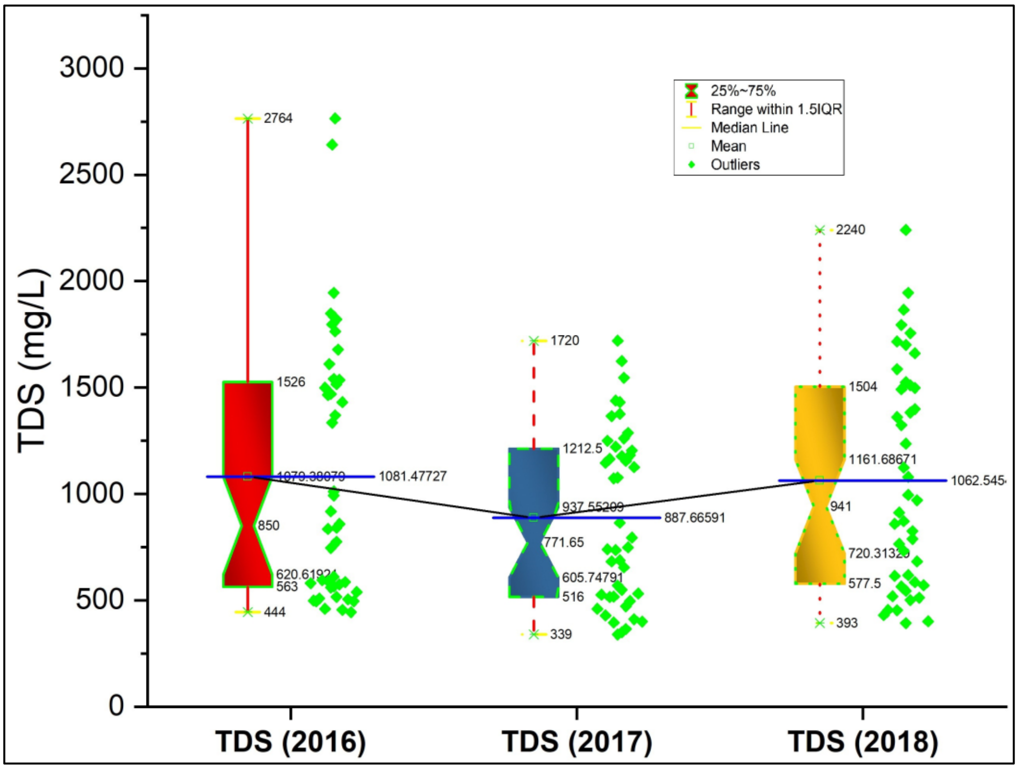
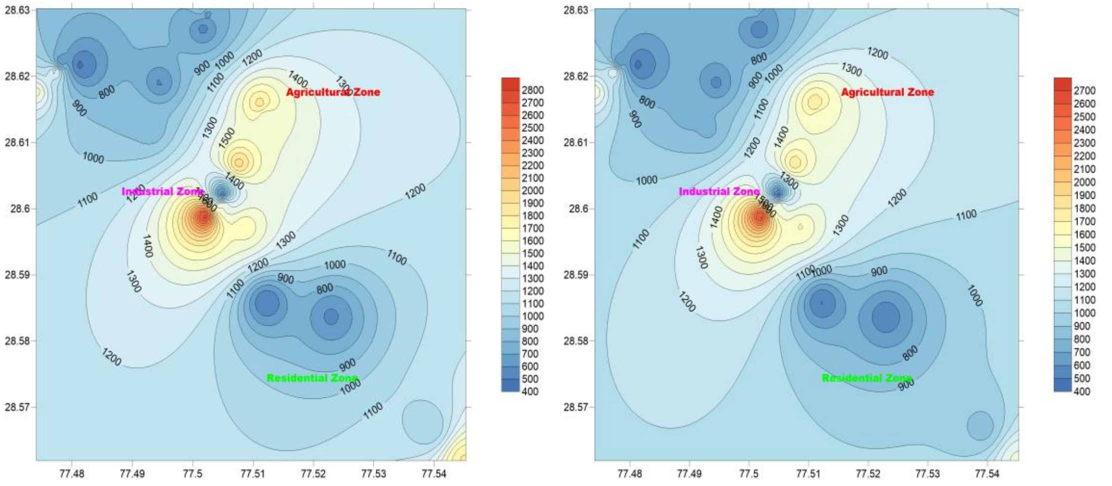
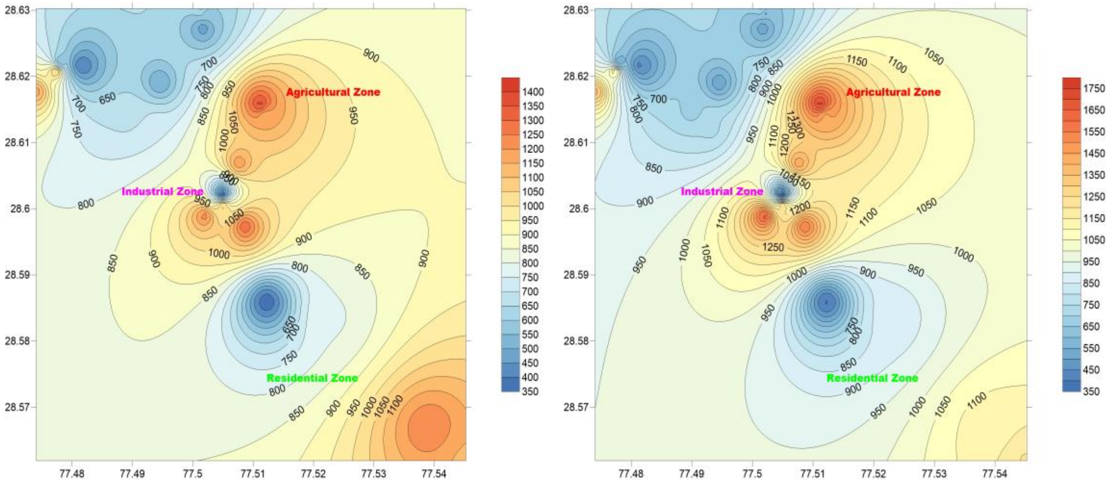


Fig. 5.2.1.14 Box and Whisker plot of TDS in Groundwater samples during study period (2016-2018)



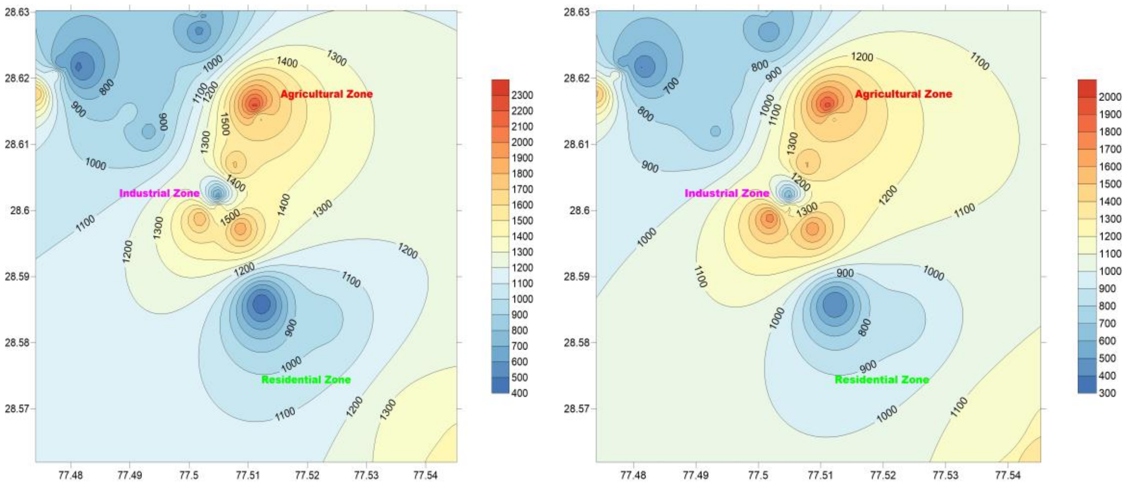
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.15 Spatial distribution of TDS in Groundwater samples of study Area during study period (2016-2018)

5.1.1.4 Turbidity

Turbidity of water specify the occurrence of suspended matters (sand, silt, inorganic & organic substances) in it. Turbidity expresses the cloudiness of water. In natural water, turbidity is due to disturbance of sediments, influx of contaminated water, excessive growth of flora and fauna etc. High tubidity of water reduces the trasmittance of light through water. It also makes water unpalatable. Although most of the turbidity causing particles have no health effects but visible turbidity indicates the presence of hazardous constituents. At very high level, turbidity of water affects domestic and industrial working (staining of materials of machines, fittings, clothes etc.).

Table - 5.2.1.7 and 5.2.1.8 are representing the turbidity in groundwater of study area during study period.

During study period, the turbidity of studied water samples ranged from 0 NTU to 56 NTU (at Dhoom Manikpur water quality station in pre-monsoon samples of 2018). In year 2016, turbidity varied from 0 to 48 NTU with a mean value of 8.86 NTU. Its maximum value was obtained from groundwater of Badhpura water quality station in post-monsoon season. During 2017, turbidity varied from 0 to 48 NTU with a mean value of 6.93 NTU. In year 2018, range of turbidity was 0 to 56 NTU with a mean of 8.61 NTU.

The mean value of turbidity in groundwater of three different zone of study area was 3.5 NTU (in agricultural zone), 4.04 NTU (in industrial zone) and 27.13 NTU (in residential zone).

Distribution plot of turbidity of groundwater samples revealed that most of the samples are located on left side of plot in the range of 0 to 10 (Fig. 5.2.1.16, 5.2.1.17 & 5.2.1.18). From the analysis of box and whiskers plot, it is clear that data was not symmetrical and many outliers were present (Fig. 5.2.1.19). A large variation in turbidity value was observed thoroughout the study period. The exceptionally high value of turbidity in residential zone of study area was also evident by spatial distribution of turbidity value of groundwater in study area (Fig. 5.2.1.20). Turbidity of groundwater in residential zone was maximum during all the sampling period.

Table - 5.2.1.7 Seasonal variation in Turbidity (in NTU) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural	S1	Duryai	Pre-monsoon	18	14	10
			Post-monsoon	5	11	4
	S2	Duryai	Pre-monsoon	1	1	4
			Post-monsoon	0	1	2
	S3	Duryai	Pre-monsoon	3	0	3
			Post-monsoon	1	0	1
	S4	Talabpur	Pre-monsoon	3	0	2
			Post-monsoon	0	0	0
Industrial	S5	Bisrakh Road	Pre-monsoon	3	1	1
			Post-monsoon	2	4	6
	S6	Bisrakh Road	Pre-monsoon	2	2	3
			Post-monsoon	1	4	4
	S7	Bisrakh Road	Pre-monsoon	45	28	31
			Post-monsoon	27	18	17
	S8	Bisrakh Road	Pre-monsoon	5	0	3
			Post-monsoon	1	0	2
	S9	Bisrakh Road	Pre-monsoon	2	2	4
			Post-monsoon	1	0	3
	S10	Khera Dharampura	Pre-monsoon	2	5	5
			Post-monsoon	4	3	1
	S11	Bishnuli	Pre-monsoon	1	1	3
			Post-monsoon	0	0	1
	S12	Achheja	Pre-monsoon	5	0	7
			Post-monsoon	1	3	6
	S13	Achheja	Pre-monsoon	4	0	2
			Post-monsoon	8	6	9
	S14	Dujana	Pre-monsoon	3	4	8
			Post-monsoon	2	1	2
	S15	Dujana	Pre-monsoon	4	0	2
			Post-monsoon	3	0	0
	S16	Dujana	Pre-monsoon	1	0	1
			Post-monsoon	0	0	0
	S17	Dujana	Pre-monsoon	1	1	0
			Post-monsoon	0	0	0
	S18	Badalpur	Pre-monsoon	4	1	1
			Post-monsoon	1	0	0
Residential	S19	Sadopur	Pre-monsoon	12	1	17
			Post-monsoon	5	4	10
	S20	Dairy Maccha	Pre-monsoon	11	5	34
			Post-monsoon	31	12	9
	S21	Dhoom Manikpur	Pre-monsoon	39	43	56
			Post-monsoon	38	39	53
	S22	Badhpura	Pre-monsoon	42	48	30
			Post-monsoon	48	42	22

Table - 5.2.1.8 Statistical Summary of Turbidity (in NTU) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	1	Duryai, Bishnuli, Dujana	0	Talabpur, Duryai, Bishnuli, Dujana	0	Achheja, Bisrakh Road, Talabpur, Duryai, Dujana	0	Bisrakh Road, Talabpur, Duryai, Bishnuli, Dujana, Badalpur	0	Dujana	0	Talabpur, Dujana, Badalpur
Max.	45	Bisrakh Road	48	Badhpura	48	Badhpura	42	Badhpura	56	Dhoom Manikpur	53	Dhoom Manikpur
Mean	9.59		8.14		7.14		6.73		10.318		6.8864	
St. Dev.	13.84		14.03		13.96		11.92		14.509		11.765	

BIS gives 1 NTU as an acceptable limit of turbidity and 5 NTU as the permissible limit of turbidity. Around 61.4% of studied water samples had turbidity greater than 1 NTU and 21.03% of samples exceeded the turbidity value of 5 NTU. Groundwater samples taken from water quality station at Badhpura, Dhoom Manikpur, Dairy Maccha, Bisrakh road and Duryai had very high value of turbidity depicting the presence of suspended substances. The source of suspended matter in groundwater was percolation of hazardous chemicals present in agricultural runoff, effluents of various industries and municipal wastes. Rajankar et al., (2011) investigated the groundwater of Bhandara district of central India and reported a range of 4.2 to 184.2 NTU (in pre-monsoon samples) and 3.8 to 79 NTU (in post-monsoon samples). Similar type of study was done by Aboyeji & Eigbokhan, (2016) near to Olusosun open dumpsite in Lagos metropolis in southwest Nigeria. Kolawole & Afolayan, (2017) also studied the groundwater of Ilorin, north-central Nigeria and reported turbidity from 2.69 to 6.31 NTU.

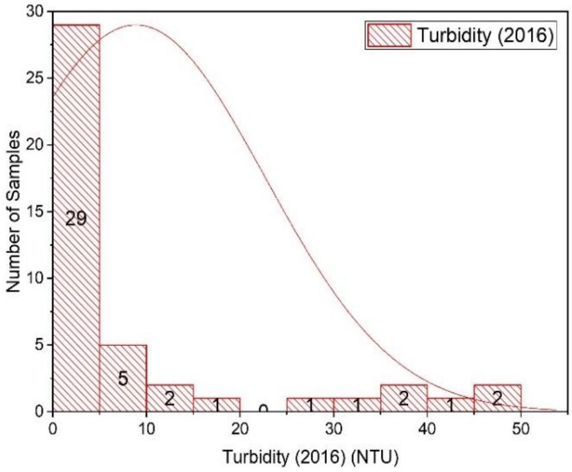


Fig. 5.2.1.16 Empirical probability distribution of Turbidity in Groundwater samples (in year 2016)

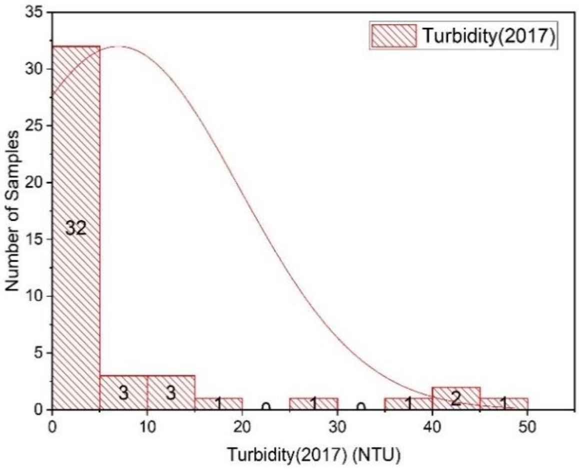


Fig. 5.2.1.17 Empirical probability distribution of Turbidity in Groundwater samples (in year 2017)

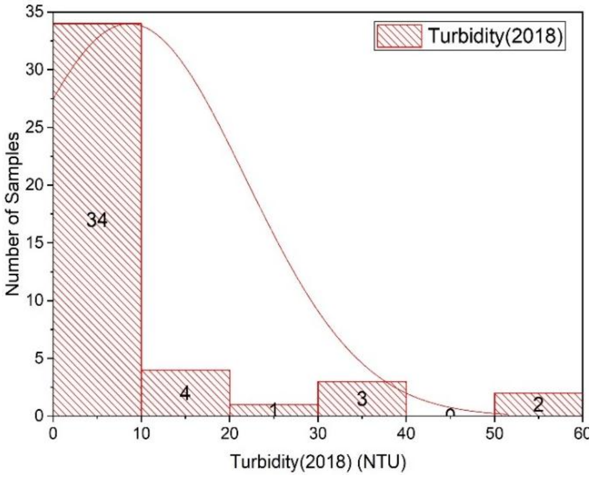


Fig. 5.2.1.18 Empirical probability distribution of Turbidity in Groundwater samples (in year 2018)

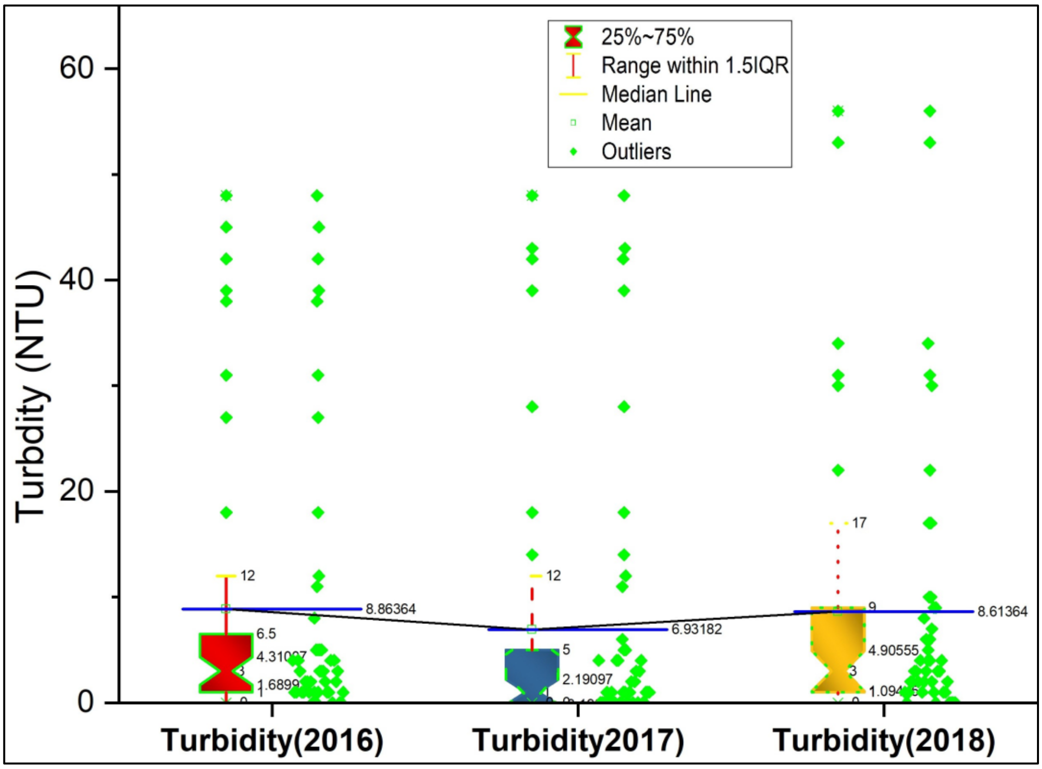
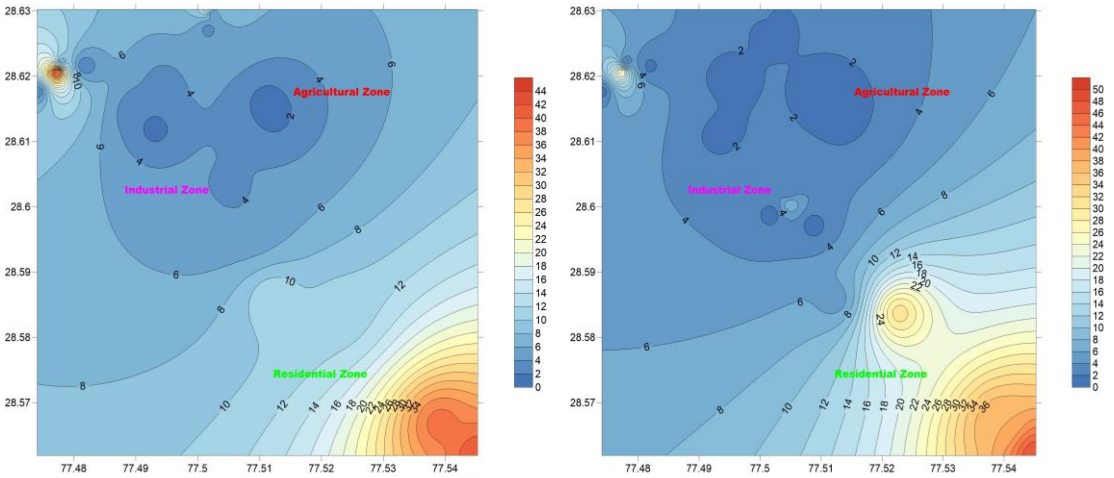
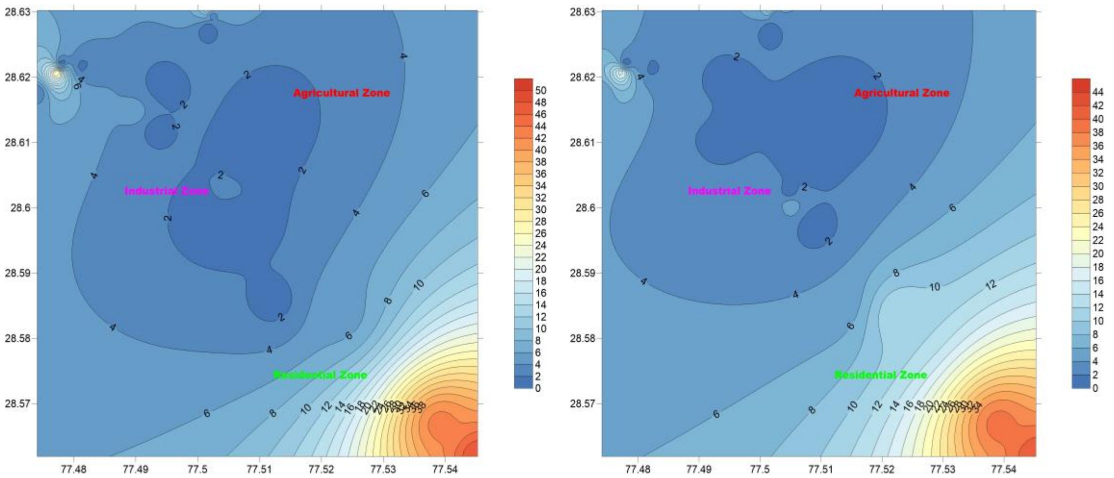


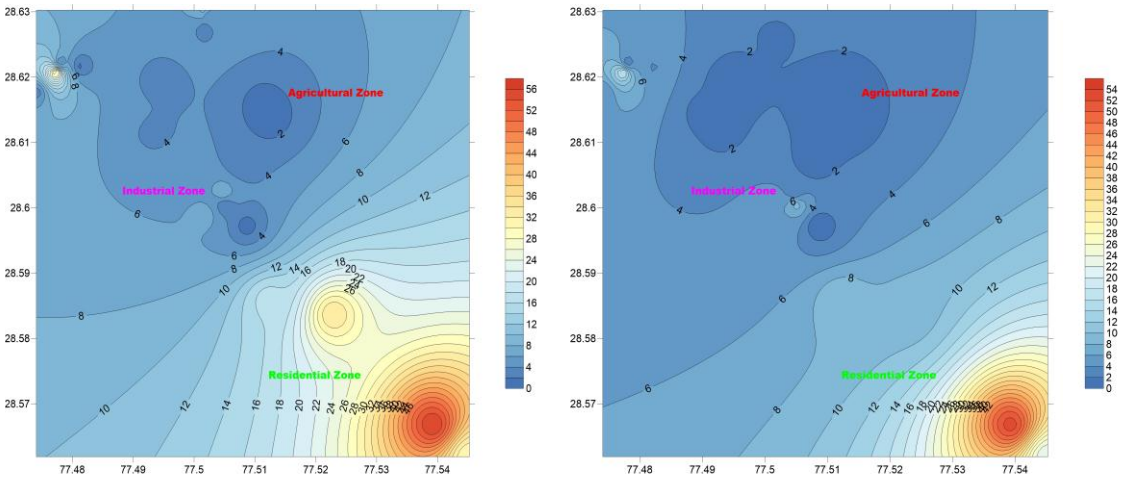
Fig. 5.2.1.19 Box and Whiskers plot of Turbidity in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.20 Spatial distribution of Turbidity in Groundwater samples of study Area during study period (2016-2018)

5.2.1.5 Total Hardness (TH)

Total hardness specifies the total concentration of calcium and magnesium (as $CaCO_3$, in mg/L). Traditionally hardness of water refers to its capacity to form lather with detergents and soaps. Boiling point of water increases with hardness. Hardness of water is responsible for scaling in water distribution system, water boilers and other water heating appliances. It is not due to specific ion but is a mixture of ions. Hardness of water is of two types – temporary hardness and permanent hardness. Temporary hardness of water is due to carbonates/bicarbonates of calcium/magnesium. Permanent hardness is due to alkaline earth sulphate and chlorides. Naturally hardness of groundwater can be increased due to dissolution of minerals present in rocks, seepage and runoff from surface water. Hard water is usually found in regions having thick layer of soiled lime stone. Hardness of ground water is comparatively higher than surface water due to weathering of rocks that contain appreciable amount of minerals like calcite, gypsum, dolomite etc. Chemical industries and mining process also contributes in hardness of water. At construction site, oxide of calcium is used in different building materials. Calcium salts are widely used in paper production, pharmaceuticals, photography, lime, de-icing salts, pigments, fertilizers, plasters and as a waste water treatment chemical (Limestone ($CaCO_3$), lime (CaO) and slaked lime ($Ca(OH)_2$)). Hardness of water is generally analysed to examine its appropriateness for domestic, recreational and industrial usage. Hard water does not cause any specific negative health impacts but it is only due to natural factor- soil rock interaction. Water is classified according to the extent of hardness as either hard or soft. According to the Taylor's & Sawyer's classification the water as soft or hard based on the following criterian-

S.No.	**Taylor's classification**		**Observed % of samples**	**Sawyer's, 1960**		**Observed % of samples**
	Concentration	**Class**		**Concentration**	**Class**	
1	<50 mg/L	Soft	-	<75 mg/L	Soft	-
2	51-100 mg/L	Moderately Soft	-	75-150 mg/L	Moderately Soft	-
3	101-150 mg/L	Slightly Hard	-	150-300 mg/L	Hard	37.12%
4	151-250 mg/L	Moderately Hard	12.12%	> 300 mg/L	Very Hard	62.88%
5	251-350 mg/L	Hard	31.81%			
6	>350 mg/L	Very Hard	56.07%			

The results of the water quality analysis with respect to total hardness at all the water quality stations of the study area are given in Table - 5.2.1.9 and 5.2.1.10.

Table - 5.2.1.9 Seasonal Variation in TH (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	392	265	418	3.80%	-2.30%	11.20%
			Post-monsoon	377	271	371			
	S2	Duryai	Pre-monsoon	300	290	307	6.70%	3.40%	10.40%
			Post-monsoon	280	280	275			
	S3	Duryai	Pre-monsoon	287	228	299	5.60%	-11.00%	12.40%
			Post-monsoon	271	253	262			
	S4	Talabpur	Pre-monsoon	330	300	466	2.40%	4.70%	12.40%
			Post-monsoon	322	286	408			
Industrial	S5	Bisrakh Road	Pre-monsoon	230	213	225	3.90%	2.00%	10.70%
			Post-monsoon	221	208	201			
	S6	Bisrakh Road	Pre-monsoon	610	557	683	5.40%	3.10%	13.60%
			Post-monsoon	577	540	590			
	S7	Bisrakh Road	Pre-monsoon	563	471	483	4.30%	3.60%	10.10%
			Post-monsoon	539	454	434			
	S8	Bisrakh Road	Pre-monsoon	295	282	299	0.00%	4.50%	11.00%
			Post-monsoon	295	270	266			
	S9	Bisrakh Road	Pre-monsoon	258	228	273	1.60%	-1.80%	12.10%
			Post-monsoon	254	232	240			
	S10	Khera Dharampura	Pre-monsoon	487	437	515	9.40%	10.30%	12.80%
			Post-monsoon	441	392	449			
	S11	Bishnuli	Pre-monsoon	296	242	328	2.00%	0.80%	7.30%
			Post-monsoon	290	240	304			
	S12	Achheja	Pre-monsoon	1005	591	645	4.50%	1.40%	2.20%
			Post-monsoon	960	583	631			
	S13	Achheja	Pre-monsoon	504	454	499	4.40%	7.90%	11.20%
			Post-monsoon	482	418	443			
	S14	Dujana	Pre-monsoon	306	219	393	8.80%	2.70%	6.90%
			Post-monsoon	279	213	366			
	S15	Dujana	Pre-monsoon	722	596	623	10.80%	10.10%	13.00%
			Post-monsoon	644	536	542			
	S16	Dujana	Pre-monsoon	667	674	805	3.70%	8.80%	13.50%
			Post-monsoon	642	615	696			
	S17	Dujana	Pre-monsoon	484	495	523	2.90%	3.80%	15.10%
			Post-monsoon	470	476	444			
	S18	Badalpur	Pre-monsoon	541	563	634	6.80%	5.50%	13.20%
			Post-monsoon	504	532	550			
Residential	S19	Sadopur	Pre-monsoon	336	272	283	1.20%	5.90%	6.70%
			Post-monsoon	332	256	264			
	S20	Dairy Maccha	Pre-monsoon	197	287	320	3.60%	1.70%	6.60%
			Post-monsoon	190	282	299			
	S21	Dhoom Manikpur	Pre-monsoon	413	512	517	4.10%	14.60%	13.70%
			Post-monsoon	396	437	446			
	S22	Badhpura	Pre-monsoon	541	364	485	16.30%	0.80%	1.90%
			Post-monsoon	453	361	476			

Table - 5.2.1.10 Statistical Summary of TH (in mg/L) in Groundwater samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	197	Dairy Maccha	190	Dairy Maccha	213	Bisrakh Road	208	Bisrakh Road	225	Bisrakh Road	201	Bisrakh Road
Max.	1005	Achheja	960	Achheja	674	Dujana	615	Dujana	805	Dujana	496	Dujana
Mean	443.8		450.3		388.17		367.5		455.5		407.1	
St. Dev.	193.69		193.55		148.91		134.87		156.2		136.5	

The total hardness of groundwater varied from 190 to 1005 mg/L with a mean value of 413.9 mg/L in the whole study period. Highest value of total hardness 1005 mg/L was found at Achheja water quality station in pre-monsoon sample of the year 2016 and the minimum 190 mg/L at Dairy Maccha water quality station in post-monsoon sample of the year 2016. During 2016, the variation in total hardness in the studied samples, was from 190 to 1005 mg/L while, in 2017 it ranged from a minimum of 208 mg/L to a maximum of 674 mg/L. It was observed that values varied from 201 to 805 mg/L during 2018.

Total hardness value of analysed water samples in agricultural zone ranged from 228 mg/L to 466 mg/L. In industrial zone total hardness extended from 201 mg/L to 1005 mg/L. TH of groundwater in residential area was 190 mg/L to 541 mg/L. A wide variation was observed in TH value of groundwater throughout the study period. This significant variation in TH was due to different land use pattern of study area. Naturally TH of groundwater is caused from the dissolution of calcium and magnesium ions from the sedimentary rocks. Leachates also contribute to the TH of groundwater. The mean value of TH was 14.08 mg/L, 456.91 mg/L and 363.29 mg/L in agricultural, industrial and residential zone respectively. The maximum mean value of TH in industrial zone showed the effect of industrial leachate on groundwater hardness.

Percent change from pre-monsoon to post-monsoon shows that TH value decreased in post-monsoon samples except few water quality stations in year 2017. These water quality stations were in agricultural zone of study area. Higher dissolution of calcium and magnesium with seepage and runoff from soil was the source of hardness in groundwater. It was also observed that maximum dilution in post-monsoon samples occured in year 2018.

Few samples in year 2016, 2018 showed high value on histogram, as reflected by their location on the right side of plot (Fig. 5.2.1.21, 5.2.1.22, 5.2.1.23). These high values were also evidenced by outliers in quantile plot (Fig. 5.2.1.24). These values were separated from the rest of the samples, and do not appear as a part of continuous distribution. Majority of samples were located on left side of distribution plot. In year 2016 & 2017, mean value was higher than median value. High TH value in samples collected from industrial zone was also explained from spatial distribution plot of TH of groundwater samples in study area (Fig. 5.2.1.25).

BIS recommended the limit of TH for drinking purpose to be 200 mg/L and the permissible BIS limit for hardness is 600 mg/L in the absence of any other alternative source. About 98.5% of samples were above the acceptable limit of TH given by BIS while 12.12% of samples exceeded the permissible limit of TH. The samples which exceeded the permissible limit were collected from the water quality stations of Bisrakh road, Achheja, Dujana and Badalpur in industrial zone. Rezaei & Hassani (2018) reported TH value 15.56 mg/L to 441 mg/L in groundwater samples of Isfahan province in Iran. Similar types of results were obtained by Srinivas et al., (2002); Prakash and Somashekhar (2006) and Pavendan et al., (2011).

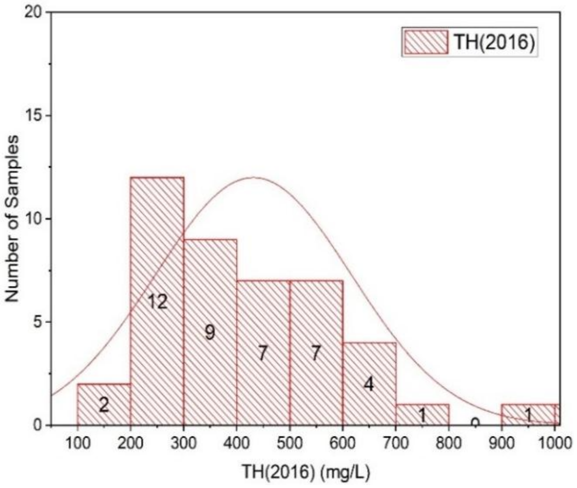


Fig. 5.2.1.21 Empirical probability distribution of TH in Groundwater samples (in year 2016)

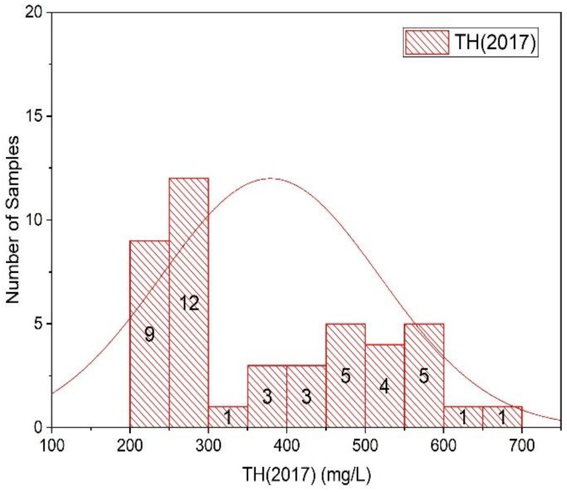


Fig. 5.2.1.22 Empirical probability distribution of TH in Groundwater samples (in year 2017)

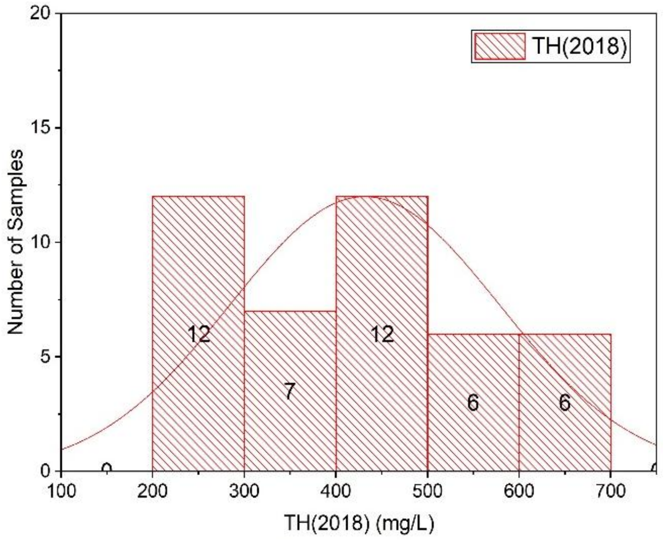


Fig. 5.2.1.23 Empirical probability distribution of TH in Groundwater samples (in year 2018)

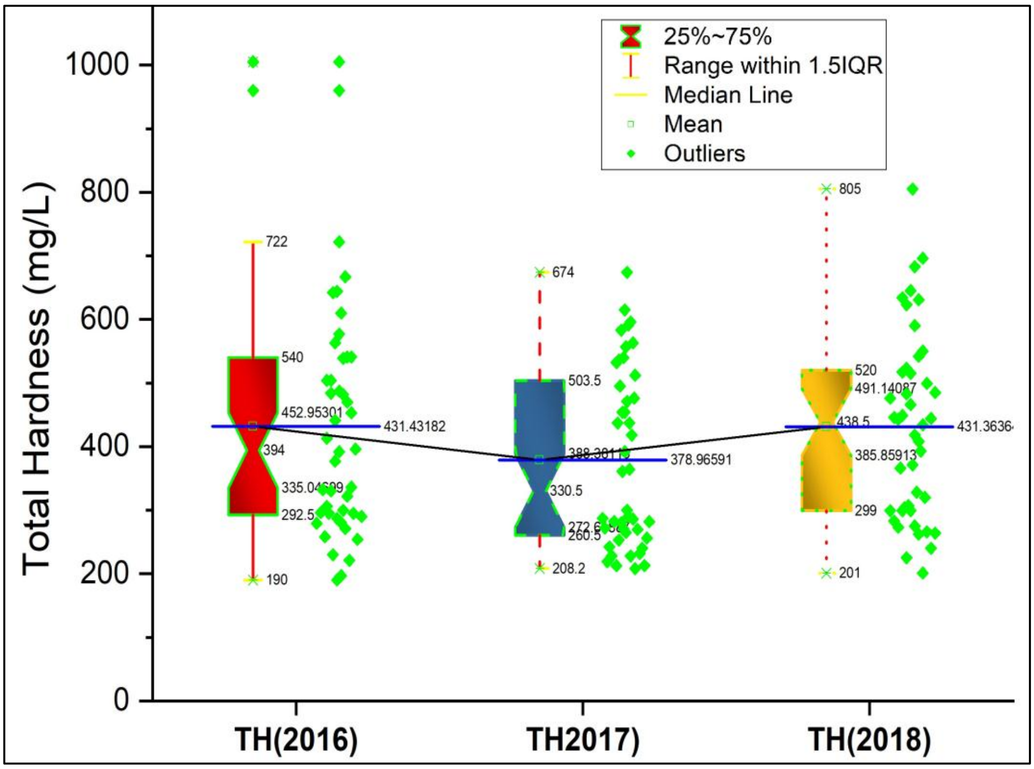
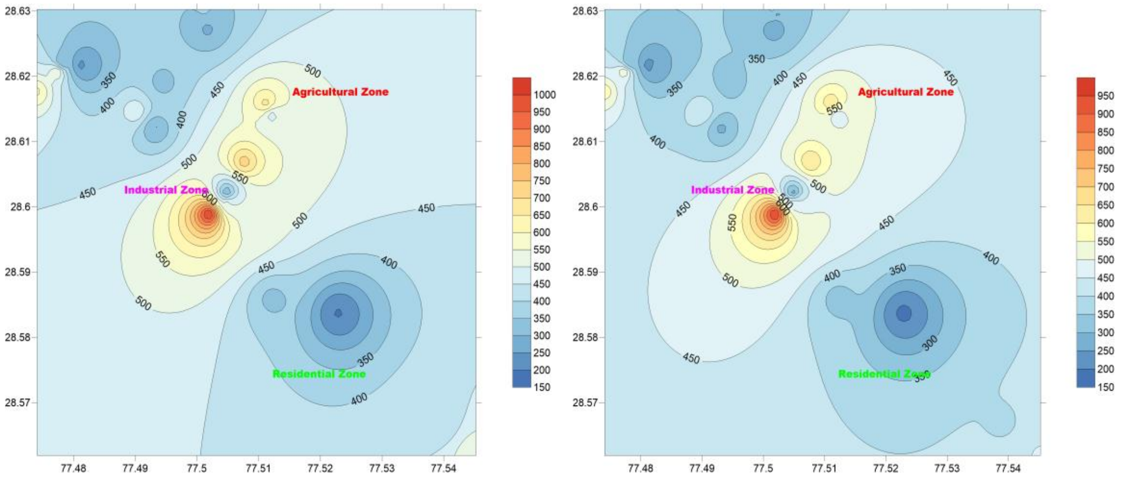
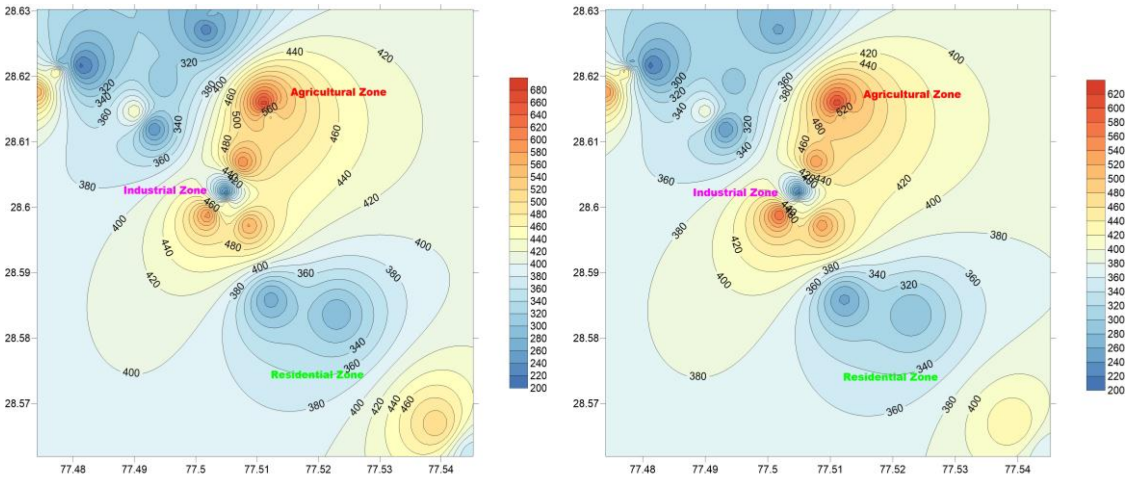


Fig. 5.2.1.24 Spatial distribution of TH in Groundwater samples of study area during study period (2016-2018)



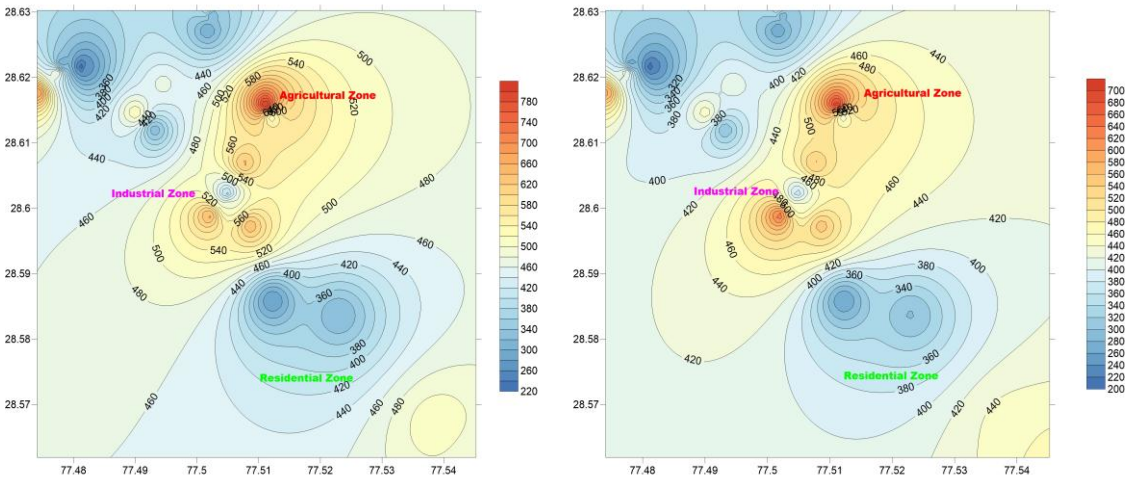
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.25 Spatial distribution of TH in Groundwater samples of study Area during study period (2016-2018)

5.2.1.6. Calcium

Calcium is present in natural water bodies in sufficient amount. It occurs in groundwater due to interaction of water and mineral present in the rock. The quantity of calcium in natural water depends upon the type of rock. It may vary from 10 to 100 mg/L. Calcium contributes to hardness of water and produce scaling. It is generally deposites in water distribution pipes and reduces the corrosion. The natural concentration of calcium in groundwater can be influenced by industrial waste. Calcium ion has a strong affinity to get adsorb on soil particles. Its quanity in natural water depends upon the occurrence of other ions. Cation exchange process influences calcium content of natural water. Sodium ions get exchange with calcium ion during the percolation of water (natural softening of water). At higher pH, calcium is precipitated as $CaCO_3$ leading to the lesser concentration of calcium ions. Calcium is an important nutrient required by various organisms.

Fortunately, calcium content of drinking water has no negative health impacts on human beings up to level of 1800 mg/L. Infact, person consuming water containing certain amount of calcium is likely to have less chance of heart trouble or cardiac disorders. But calcium concentrations above 75 mg/L, cause encrustation on water supply therefore BIS has set a desirable value of calcium as 75 mg/L in drinking water, whereas its permissible limit has been given as 200 mg/L in the absence of alternative water source.

The calcium trend in pre-monsoon and post-monsoon samples of study area in three consecutive years (2016-2018) is given in Table - 5.2.1.11 and 5.2.1.12.

Calcium concentration in groundwater of study area was recorded from 9.62 mg/L to 214.88 mg/L during study period. During 2016 the variation in calcium in the groundwater was from 9.62 – 214.88 mg/L while, in 2017 it varied from a minimum of 11.70 mg/L to a maximum of 141.50 mg/L. It was observed that values ranged from 12.21 to 167.4 mg/L during 2018. In year 2016 it was found maximum at Achheja water quality station and minimum at Dairy Maccha water quality station with a mean of 67.28 mg/L and in year 2017, the minimum calcium content was observed at Dhoom Manikpur site and maximum at Dujana site with a mean of 57.37 mg/L. In 2018 it was found maximum at Dujana site and minimum at Dhoom Manikpur site with a mean of 64.41 mg/L.

Table - 5.2.1.11 Seasonal Variation in Calcium concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	41.45	33.20	41.19	8.00%	-8.10%	13.00%
			Post-monsoon	38.13	35.90	35.83			
	S2	Duryai	Pre-monsoon	24.40	24.40	25.03	8.00%	5.00%	13.00%
			Post-monsoon	22.45	23.18	21.78			
	S3	Duryai	Pre-monsoon	33.70	24.40	33.40	5.80%	-49.70%	13.60%
			Post-monsoon	31.76	36.53	28.86			
	S4	Talabpur	Pre-monsoon	22.00	20.00	30.40	2.00%	5.00%	13.00%
			Post-monsoon	21.56	19.00	26.45			
Industrial	S5	Bisrakh Road	Pre-monsoon	28.80	23.60	23.35	1.00%	3.00%	13.00%
			Post-monsoon	28.52	22.89	20.31			
	S6	Bisrakh Road	Pre-monsoon	146.93	134.80	165.40	6.00%	3.00%	13.00%
			Post-monsoon	138.12	130.76	143.90			
	S7	Bisrakh Road	Pre-monsoon	33.60	28.00	30.71	3.50%	3.00%	13.00%
			Post-monsoon	32.42	27.16	26.72			
	S8	Bisrakh Road	Pre-monsoon	22.46	21.60	21.40	2.00%	8.30%	13.00%
			Post-monsoon	22.02	19.81	18.62			
	S9	Bisrakh Road	Pre-monsoon	26.30	23.20	25.15	-0.40%	-1.30%	13.00%
			Post-monsoon	26.40	23.50	21.88			
	S10	Khera Dharampura	Pre-monsoon	19.45	16.80	19.48	6.00%	9.80%	9.40%
			Post-monsoon	18.29	15.15	17.65			
	S11	Bishnuli	Pre-monsoon	16.83	15.60	22.95	0.30%	3.00%	7.80%
			Post-monsoon	16.78	15.13	21.15			
	S12	Achheja	Pre-monsoon	214.88	126.40	136.26	5.00%	2.00%	2.90%
			Post-monsoon	204.14	123.87	132.31			
	S13	Achheja	Pre-monsoon	115.50	105.00	114.66	4.00%	9.00%	11.00%
			Post-monsoon	110.88	95.55	102.05			
	S14	Dujana	Pre-monsoon	42.64	32.80	57.45	8.40%	3.70%	12.90%
			Post-monsoon	39.07	31.58	50.02			
	S15	Dujana	Pre-monsoon	165.60	131.20	140.50	10.10%	10.00%	13.00%
			Post-monsoon	148.80	118.08	122.24			
	S16	Dujana	Pre-monsoon	140.09	141.50	167.40	3.00%	9.40%	14.20%
			Post-monsoon	135.88	128.20	143.60			
	S17	Dujana	Pre-monsoon	124.23	123.00	129.89	3.00%	4.00%	15.30%
			Post-monsoon	120.50	118.08	110.00			
	S18	Badalpur	Pre-monsoon	132.30	135.00	153.90	6.00%	5.00%	13.00%
			Post-monsoon	124.36	128.25	133.89			
Residential	S19	Sadopur	Pre-monsoon	18.24	15.20	15.66	0.70%	1.10%	11.00%
			Post-monsoon	18.12	15.03	13.93			
	S20	Dairy Maccha	Pre-monsoon	9.62	14.80	16.28	-32.80%	1.00%	12.00%
			Post-monsoon	12.78	14.65	14.33			
	S21	Dhoom Manikpur	Pre-monsoon	18.67	13.60	14.04	10.00%	14.00%	13.00%
			Post-monsoon	16.80	11.70	12.21			
	S22	Badhpura	Pre-monsoon	130.00	85.60	111.52	19.20%	5.80%	-8.10%
			Post-monsoon	105.00	80.62	120.50			

Table-5.12 Statistical Summary of Calcium (in mg/L) in Groundwater Samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	9.62	Dairy Maccha	12.78	Dairy Maccha	13.6	Dhoom Manikpur	11.70	Dhoom Manikpur	14.04	Dhoom Manikpur	12.21	Dhoom Manikpur
Max.	214.88	Achheja	204.14	Achheja	141.5	Dujana	130.76	Bisrakh Road	167.4	Dujana	143.9	Bisrakh Road
Mean	69.44		65.13		58.62		56.12		68		60.83	
St. Dev.	62.58		58.04		51.06		47.47		57.72		51.82	

From the Table – 5.2.1.11, it is observed that in agricultural zone, calcium concentration varied from 19.0 to 41.45 mg/L with a mean value of 28.96 mg/L. In industrial zone, calcium content in groundwater was recorded from 15.13 to 214.88 mg/L with mean value of 80.06 mg/L. The amount of calcium in residential zone ranged between 9.62 to 130 mg/L providing a mean value of 37.45 mg/L. The mean value of calcium in industrial zone is higher than the acceptable limit of calcium given by BIS. The higher calcium content in groundwater of industrial zone indicates the percolation of leachate into ground aquifers. It is observed that higher calcium values at sites of residential zone may be due to the addition of calcium salts from detergents and soaps carried through domestic wastes.

Percent change in calcium content of groundwater samples from pre-monsoon to post-monsoon season showed lowering in calcium content except in few samples. Calcium content of sample S3 and S20 increased in post-monsoon season of year 2017 and 2016 respectively.

The empirical probability distribution plots of calcium in analysed samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.1.26, 5.2.1.27, & 5.2.1.28. Distribution plots depicts that most of the analysed samples have calcium content lesser than 50 mg/L. From the box – whisker plot it is clear that the data was asymmetrically distributed during study period (Fig. 5.2.1.29). Spatial distribution of calcium of groundwater in study area is given in Fig. 5.2.1.30. Darker points in contour graphs indicates the high concentration of calcium in groundwater samples at that places.

About 63.6% of analysed samples have calcium concentration well below the acceptable limit of BIS for drinking water. Nearly 34.9% of samples were above the acceptable limit but below the permissible limit and hence can be used for drinking after purification. Tay, (2004) noted calcium concentration in range of 19.2 mg/L to 361 mg/L with the mean of 107.5 mg/L in ground water. Sharma, (2014) studied ground water quality in Muktsar, Punjab and reported that amount of calcium in ground water varied from 66 mg/L to 318 mg/L. Rezaei & Hassani, (2018) reported a range of 0.81 355 mg/L calcium content in groundwater samples of Isfahan province in Iran.

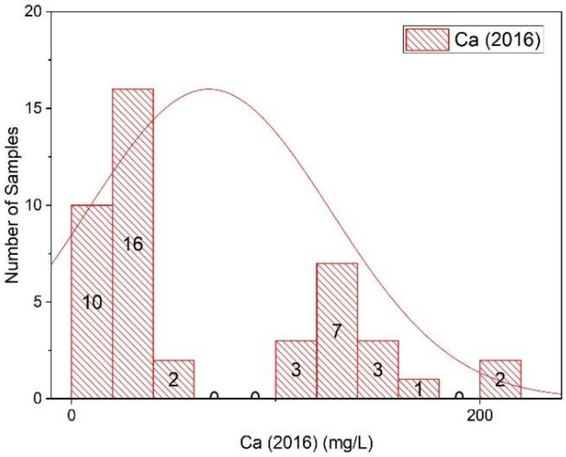


Fig. 5.2.1.26 Empirical probability distribution of Calcium concentration in Groundwater samples (in year 2016)

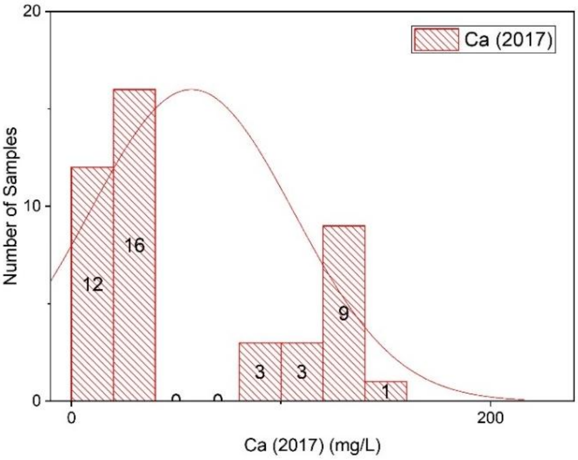


Fig. 5.2.1.27 Empirical probability distribution of Calcium concentration in Groundwater samples (in year 2017)

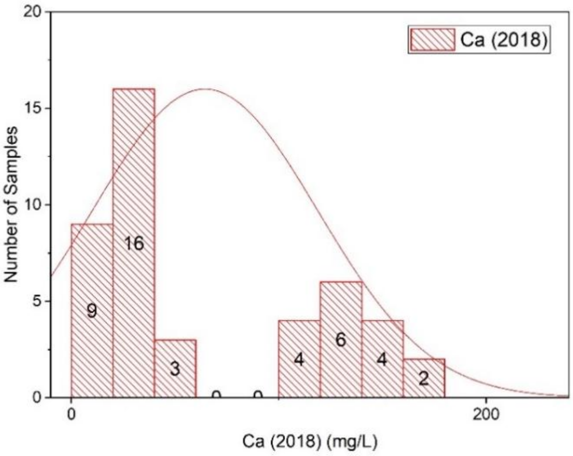


Fig. 5.2.1.28 Empirical probability distribution of Calcium concentration in Groundwater samples (in year 2018)

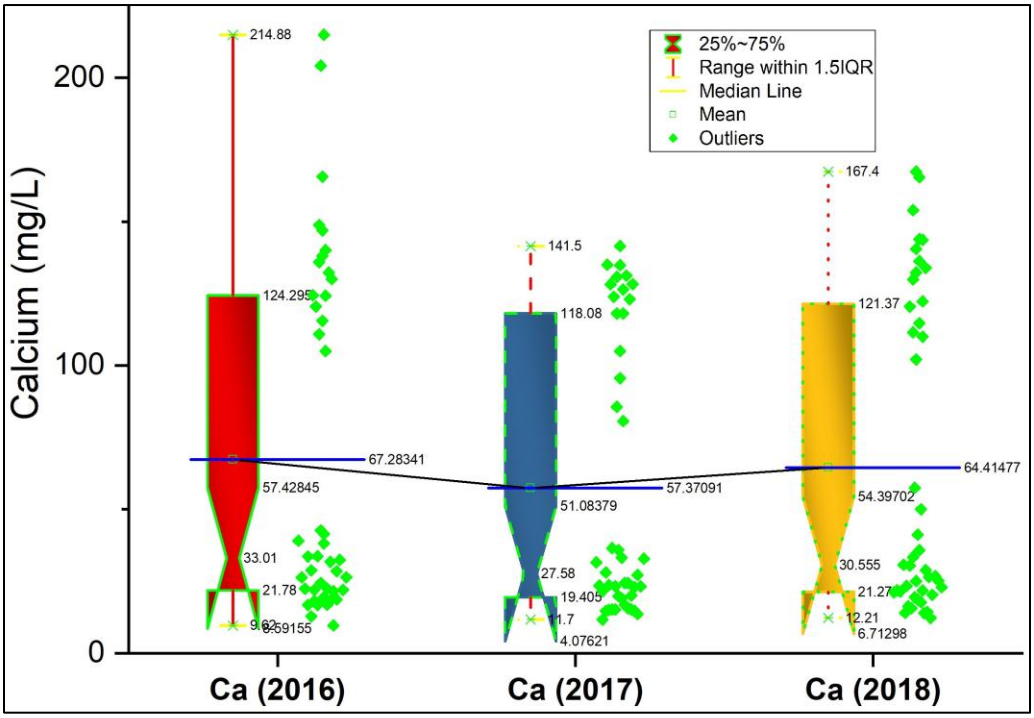
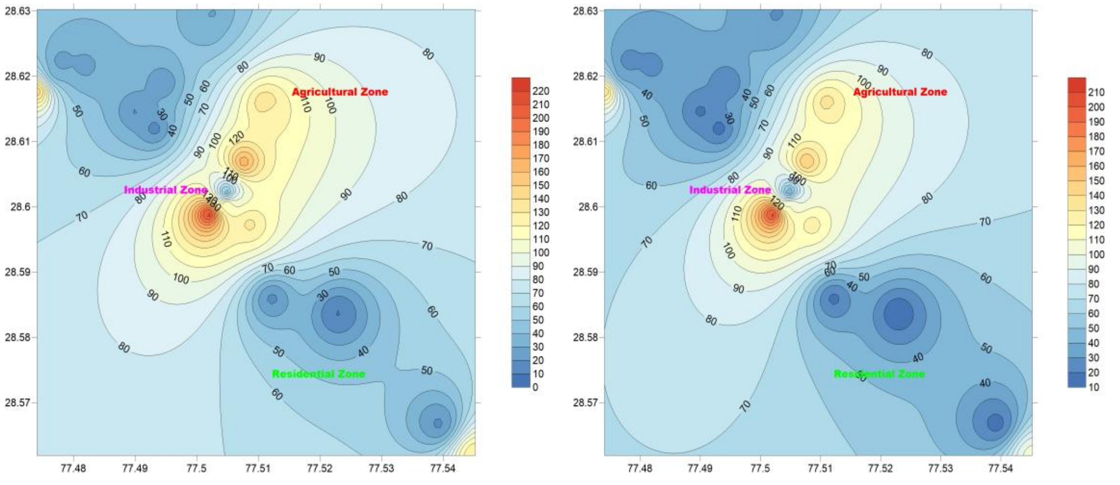
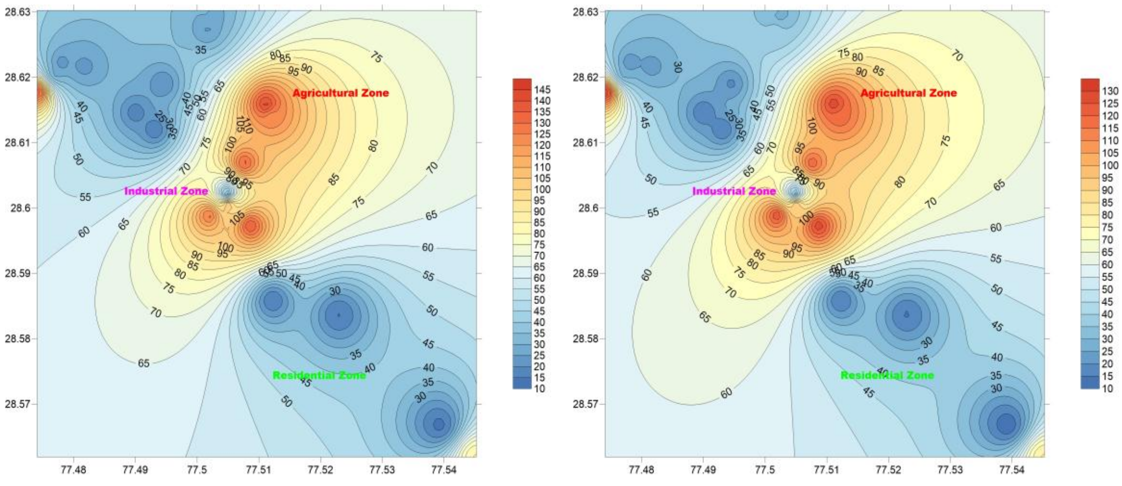


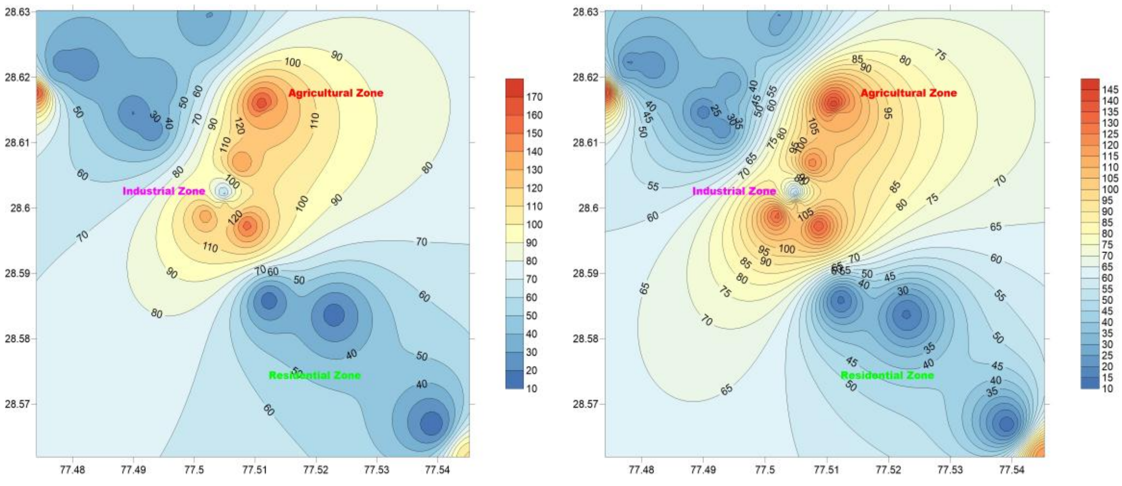
Fig. 5.2.1.29 Box and Whisker plot of calcium concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) **2016 (Post-Monsoon)**



2017 (Pre-Monsoon) **2017 (Post-Monsoon)**



2018 (Pre-Monsoon) **2018 (Post-Monsoon)**

Fig. 5.2.1.30 Spatial distribution of Calcium in Groundwater samples of study Area during study period (2016-2018)

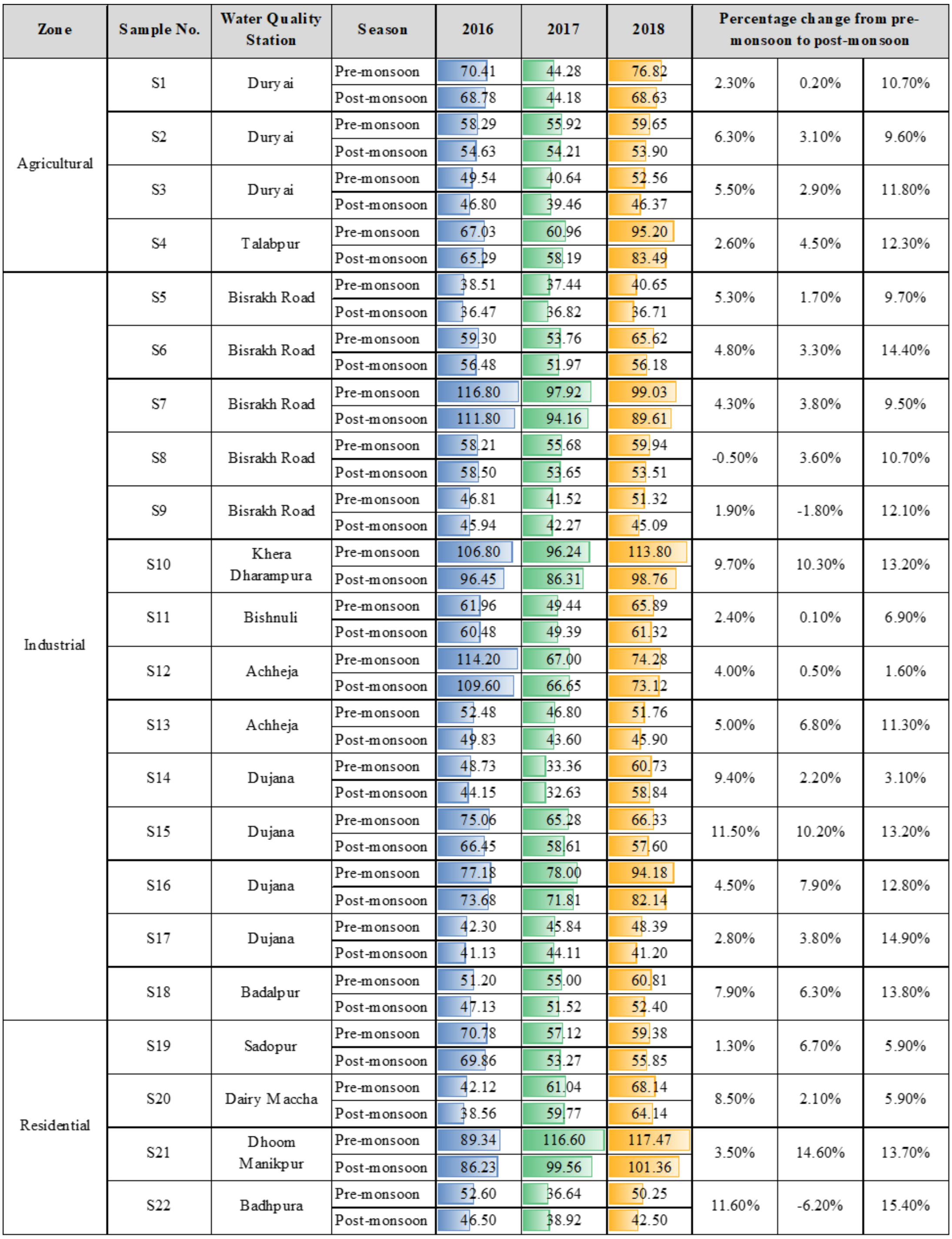
5.2.1.7 Magnesium

Magnesium has no toxic effects on human beings at the concentration which is generally found in unpolluted waters. But magnesium along with sulphate in drinking water is laxative to human beings. Drinking water with magnesium concentration above 500 mg/L has unpleasant taste. Like calcium ions, magnesium is naturally present in ground and surface water. The content of magnesium ions in surface water is, as a rule, considerably lower than the concentration of calcium ions. Salts of magnesium may also be present in municipal waste and industrial effluents. Magnesium concentration also depends upon the presence of other cations. In between the soil layers, water naturally becomes soft due to the excanhge of magnesium with sodium. It is necessary to know the magnesium hardness or the amount of magnesium ion in order to calculate the lime requirement in lime ash softening.

The results of the water quality analysis with respect to magnesium of all the twenty-two sampling stations of the study area are shown in Table - 5.2.1.13 and 5.2.1.14.

The concentration of magnesium varied from 32.63 to 117.5 mg/L with the mean value of 62.52 mg/L during the study period. Minimum value of 32.63 mg/L was recorded from Dujana water quality station in post-monsoon sample of year 2017 and maximum value of 117.5 mg/L was recorded from Dhoom Manikpur water quality station in pre-monsoon sample of year 2018. During 2016 the variation in magnesium of groundwater was from 36.47 – 116.8 mg/L while, in 2017 it ranged from a minimum of 32.63 mg/L to a maximum of 116.6 mg/L. It was observed that values ranged from 36.71 to 117.5 mg/L during 2018. In year 2016 it was found maximum at Bisrakh water quality station and in year 2017 the minimum magnesiun concentration was observed at Dujana water quality station and maximum at Dhoom Manikpur with a mean of 57.44 ± 19.66 mg/L. In 2018 it was found maximum at Dhoom Manikpur site and minimum at Bisrakh Road water quality station with a mean of 65.93 ± 20.13 mg/L.

Table - 5.2.1.13 Seasonal Variation in Magnesium concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018



Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	70.41	44.28	76.82	2.30%	0.20%	10.70%
			Post-monsoon	68.78	44.18	68.63			
	S2	Duryai	Pre-monsoon	58.29	55.92	59.65	6.30%	3.10%	9.60%
			Post-monsoon	54.63	54.21	53.90			
	S3	Duryai	Pre-monsoon	49.54	40.64	52.56	5.50%	2.90%	11.80%
			Post-monsoon	46.80	39.46	46.37			
	S4	Talabpur	Pre-monsoon	67.03	60.96	95.20	2.60%	4.50%	12.30%
			Post-monsoon	65.29	58.19	83.49			
Industrial	S5	Bisrakh Road	Pre-monsoon	38.51	37.44	40.65	5.30%	1.70%	9.70%
			Post-monsoon	36.47	36.82	36.71			
	S6	Bisrakh Road	Pre-monsoon	59.30	53.76	65.62	4.80%	3.30%	14.40%
			Post-monsoon	56.48	51.97	56.18			
	S7	Bisrakh Road	Pre-monsoon	116.80	97.92	99.03	4.30%	3.80%	9.50%
			Post-monsoon	111.80	94.16	89.61			
	S8	Bisrakh Road	Pre-monsoon	58.21	55.68	59.94	-0.50%	3.60%	10.70%
			Post-monsoon	58.50	53.65	53.51			
	S9	Bisrakh Road	Pre-monsoon	46.81	41.52	51.32	1.90%	-1.80%	12.10%
			Post-monsoon	45.94	42.27	45.09			
	S10	Khera Dharampura	Pre-monsoon	106.80	96.24	113.80	9.70%	10.30%	13.20%
			Post-monsoon	96.45	86.31	98.76			
	S11	Bishnuli	Pre-monsoon	61.96	49.44	65.89	2.40%	0.10%	6.90%
			Post-monsoon	60.48	49.39	61.32			
	S12	Achheja	Pre-monsoon	114.20	67.00	74.28	4.00%	0.50%	1.60%
			Post-monsoon	109.60	66.65	73.12			
	S13	Achheja	Pre-monsoon	52.48	46.80	51.76	5.00%	6.80%	11.30%
			Post-monsoon	49.83	43.60	45.90			
	S14	Dujana	Pre-monsoon	48.73	33.36	60.73	9.40%	2.20%	3.10%
			Post-monsoon	44.15	32.63	58.84			
	S15	Dujana	Pre-monsoon	75.06	65.28	66.33	11.50%	10.20%	13.20%
			Post-monsoon	66.45	58.61	57.60			
	S16	Dujana	Pre-monsoon	77.18	78.00	94.18	4.50%	7.90%	12.80%
			Post-monsoon	73.68	71.81	82.14			
	S17	Dujana	Pre-monsoon	42.30	45.84	48.39	2.80%	3.80%	14.90%
			Post-monsoon	41.13	44.11	41.20			
	S18	Badalpur	Pre-monsoon	51.20	55.00	60.81	7.90%	6.30%	13.80%
			Post-monsoon	47.13	51.52	52.40			
Residential	S19	Sadopur	Pre-monsoon	70.78	57.12	59.38	1.30%	6.70%	5.90%
			Post-monsoon	69.86	53.27	55.85			
	S20	Dairy Maccha	Pre-monsoon	42.12	61.04	68.14	8.50%	2.10%	5.90%
			Post-monsoon	38.56	59.77	64.14			
	S21	Dhoom Manikpur	Pre-monsoon	89.34	116.60	117.47	3.50%	14.60%	13.70%
			Post-monsoon	86.23	99.56	101.36			
	S22	Badhpura	Pre-monsoon	52.60	36.64	50.25	11.60%	-6.20%	15.40%
			Post-monsoon	46.50	38.92	42.50			

Table - 5.2.1.14 Statistical Summary of Magnesium (in mg/L) in Groundwater Samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	38.51	Bisrakh Road	36.47	Bisrakh Road	33.36	Dujana	32.63	Dujana	40.65	Bisrakh Road	36.71	Bisrakh Road
Max.	116.8	Bisrakh Road	111.8	Bisrakh Road	116.60	Dhoom Manikpur	99.56	Dhoom Manikpur	117.47	Dhoom Manikpur	101.36	Dhoom Manikpur
Mean	65.89		62.49		58.93		56.12		69.65		62.21	
St. Dev.	22.84		21.76		21.44		18.07		21.32		18.612	

On the basis of land use pattern in current study area, magnesium concentration in groundwater has significant variations. In agricultural zone magnesium concentration ranged from 39.46 to 95.2 mg/L with a mean value of 58.97 mg/L. Magnesium analysis of groundwater of industrial zone gave a minimum value of 32.63 mg/L and a maximum value of 116.8 mg/L with a mean value of 62.61 mg/L. The magnesium concentration in residential zone ranged between 36.64 and 117.47 mg/L providing a mean value of 65.75 mg/L (Table – 5.2.1.13).

The study did not show any significant seasonal variation in magnesium content of groundwater. However percent change of magnesium from pre-monsoon to post-monsoon season revealed the overall decrease in magnesium content of groundwater except at few places. Water quality stations at Bisrakh Road in year 2016 & 2017 and Badhpura in year 2017 showed increase in magnesium content in post-monsoon samples. Kumar et al., (2016) also reported decrease in magnesium content in groundwater of Lucknow after monsoon. Similarly seasonal variation in magnesium content of groundwater was also reported by many researchers like Vasanthavigar, (2010); Ezekwe et al., (2012); Magesh & Chandrasekar, (2013); Singh & Singh, (2018).

The empirical probability distribution plots of magnesium in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.1.31, 5.2.1.32 and 5.2.1.33 respectively. Most of the samples were located in the range of 40 – 60 mg/L of magnesium. Box and Whisker plot was also drawn to know the distributional characterstics of magnesium values of groundwater during study period (Fig. 5.2.1.34). Many outliers were present in quantile diagram of magnesium. Mean value of magnesium content was higher than median throughout study period. Magnesium spatial distribution map of groundwater in study area is given in Fig. 5.2.1.35. Dark patches representing high magnesium content of groundwater were present in agricultural zone and residential zone of study area.

BIS gives 30 mg/L as an acceptable limit and 100 mg/L as permissible limit for magnesium in potable water. At all the water quality stations magnesium content of groundwater exceeded the acceptable limit of BIS (30 mg/L) for magnesium in drinking water. Nearly 6.82% of analysed samples have magnesium content higher than 100 mg/L. These samples were collected from Bisrakh Road, Khera Dharampura, Achheja and Dhoom Manikpur water quality stations. The high content of magnesium in groundwater can be attributed to the dissolution of minerals like calcite, gypsum and dolomite (Rao, 1997). Singh et al., (2011) reported a range of 18 to 137 mg/L for magnesium content in groundwater of Noida region in Gautam Budh Nagar district. Singh & Hussian, (2016) analysed the groundwater samples of Greater Noida sub-basin and reported that magnesium content of groundwater was 7.5 to 120.5 mg/L. They also documented that only 25% of analysed samples were within the prescribed acceptable limit of magnesium given by BIS.

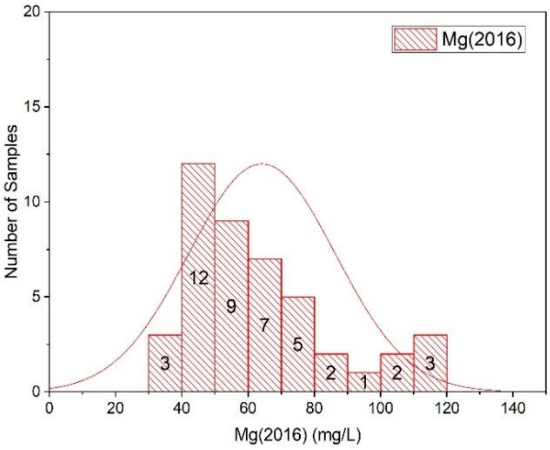


Fig. 5.2.1.31 Empirical probability distribution of Magnesium concentration in Groundwater samples (in year 2016)

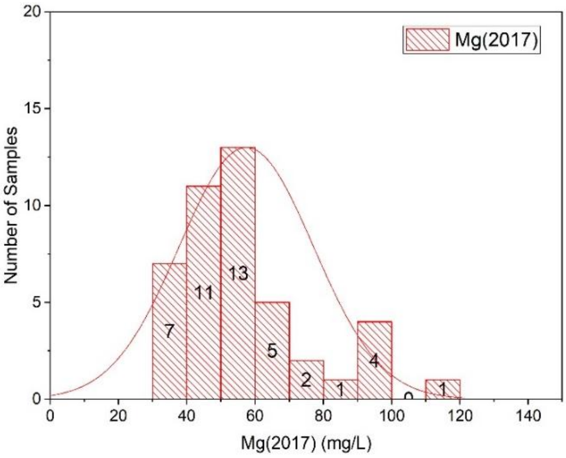


Fig. 5.2.1.32 Empirical probability distribution of Magnesium concentration in Groundwater samples (in year 2017)

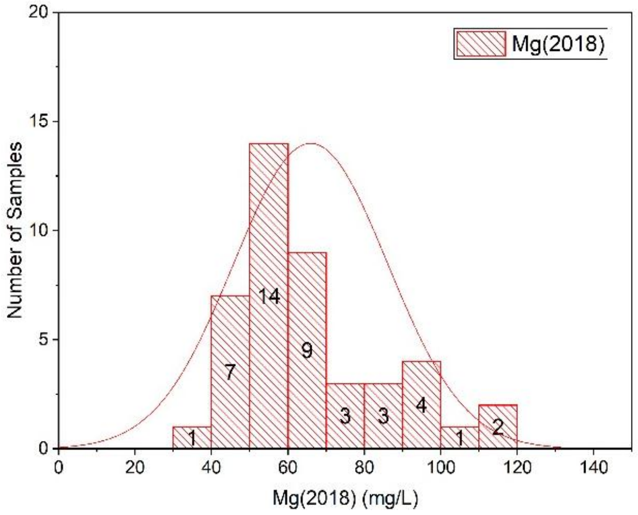


Fig. 5.2.1.33 Empirical probability distribution of Magnesium concentration in Groundwater samples (in year 2018)

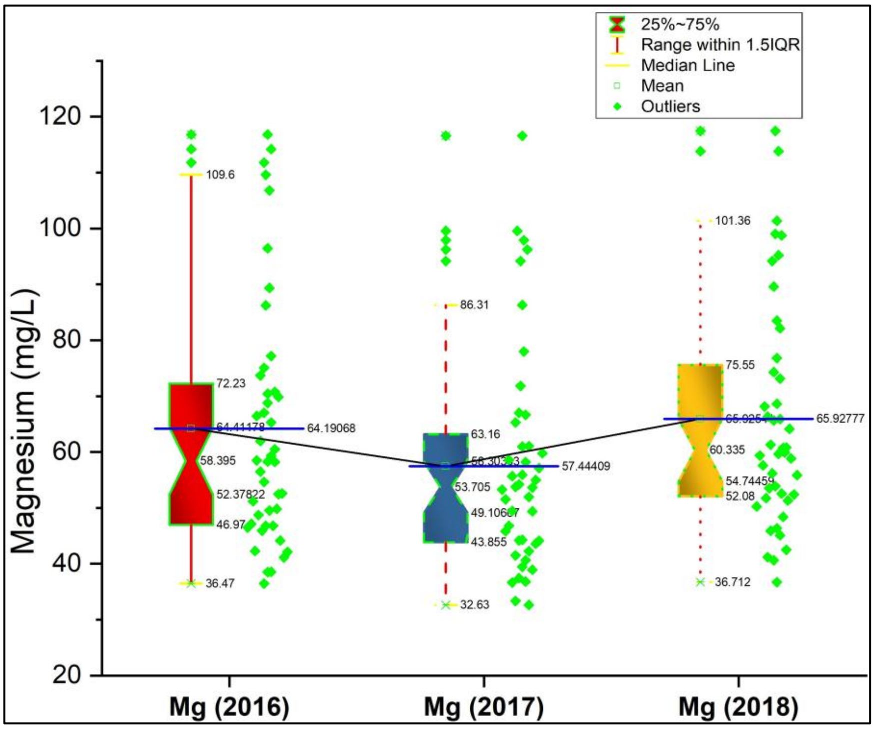
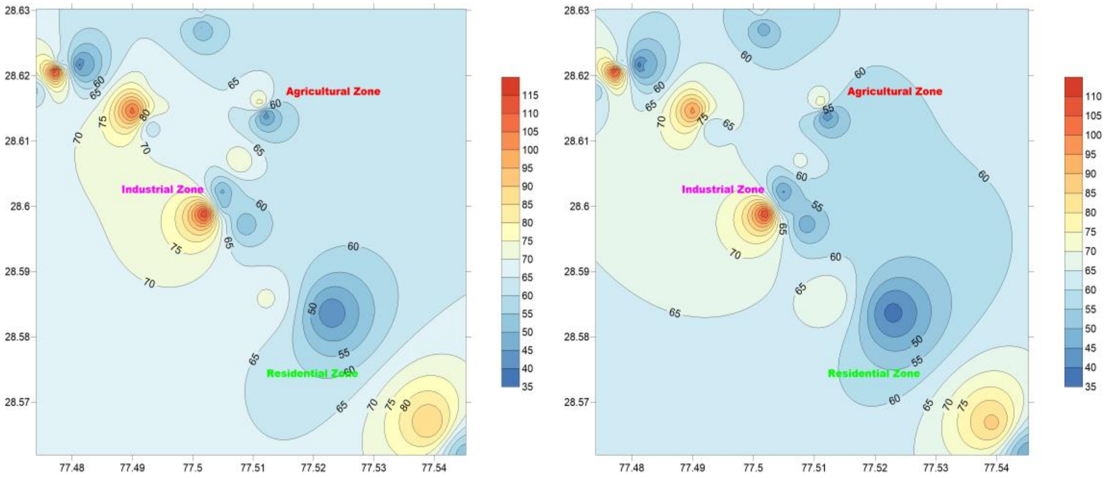
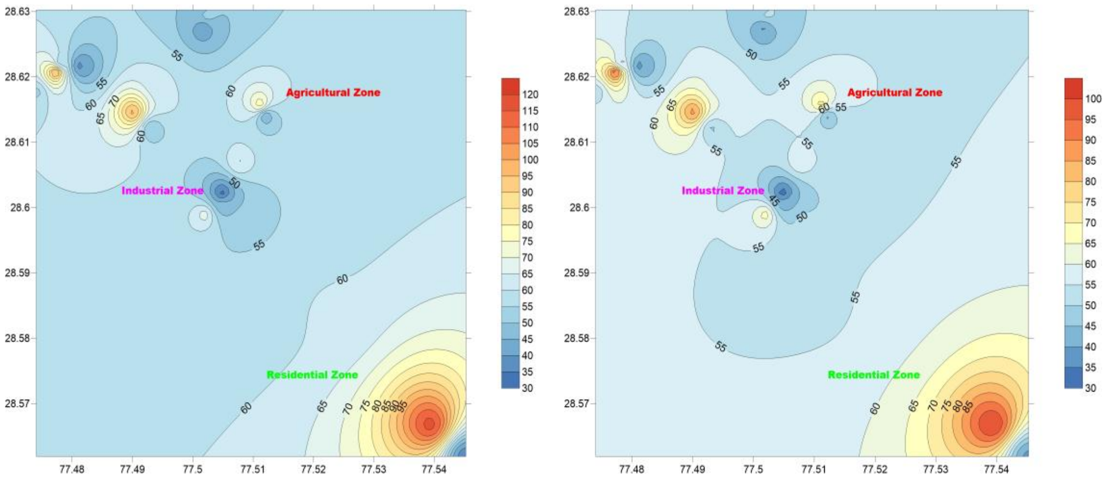


Fig. 5.2.1.34 Box and Whisker plot of Magnesium concentration in Groundwater samples during study period (2016-2018)



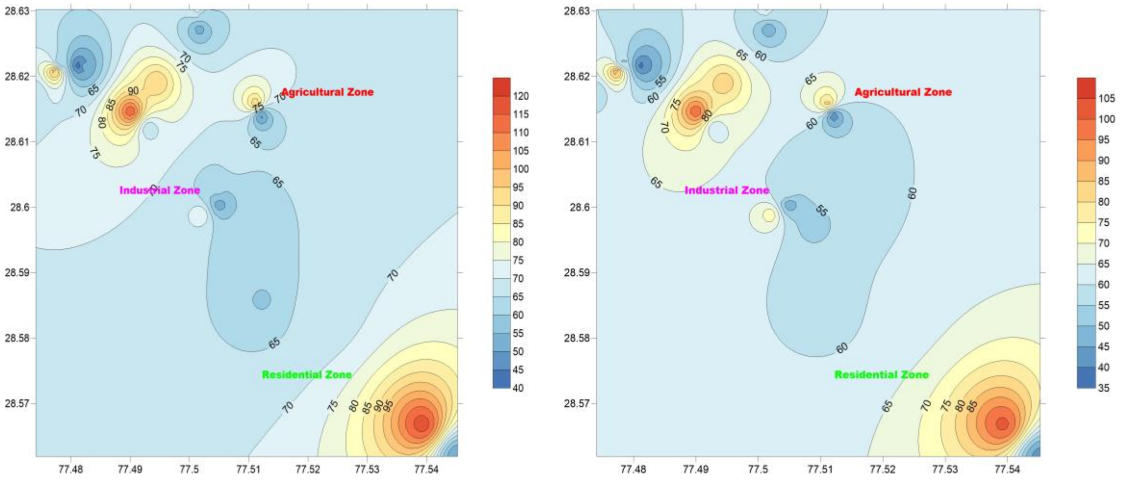
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.35 Spatial distribution of Magnesium in Groundwater samples during study period (2016-2018)

5.2.1.8 Sodium

Sodium has a vital role in all aquatic bodies and is a critical element to be considered while assessing water suitability for irrigation. It is one of the most abundant elements available in nature though never in its elemental state. Its salts are highly soluble hence present in most natural waters. Sea water is especially rich in this element. Sodium is an important element, which harms human physiology if present in high concentration. Because of this reason seawater is unsuitable for most of the human requirements such as drinking, domestic, irrigation or industrial uses.

The results of the water quality analysis with respect to sodium at all the twenty-two water quality stations of the study area are shown in Table - 5.2.1.15 and 5.2.1.16.

The concentration of sodium ranged from 6.12 to 356.1 mg/L with the mean value of 120.2 mg/L during study period. Minimum value of 6.12 mg/L was obtained from Sadopur water quality station in post-monsoon sample of year 2018 and maximum value of 356.1 mg/L was recorded from Achheja water quality station in pre-monsoon sample of year 2016. During 2016 the variation in sodium in groundwater was from 8.39 to 356.1 mg/L with a mean value of 127.67 ± 97.67 while, in 2017 it varied from a minimum of 6.42 mg/L to a maximum of 234.0 mg/L. It was observed that values ranged from 6.12 to 295.9 mg/L during 2018. In year 2016 it was found maximum at Achheja water quality station and in year 2017 the minimum sodium concentration was observed at Sadopur water quality station and maximum at Dujana with a mean of 113.88 ± 75.44 mg/L. In 2018 it was found maximum at Dujana site and minimum at Sadopur water quality station with a mean of 119 ± 86.6 mg/L.

In agricultural zone, sodium content varied from 24.85 to 109.8 mg/L with a mean value of 55.10 mg/L. The sodium concentration in industrial zone ranged between 11.2 and 356.1 mg/L providing a mean of 134.99 mg/L. Residential zone of study area also has a wide range of sodium concentration with a minimum value of 6.12 mg/L and a maximum value of 310 mg/L. In residential zone, Badhpura water quality station has maximum content of sodium in groundwater reflecting impact of domestic waste water.

Table - 5.2.1.15 Seasonal Variation in Sodium concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	101.80	109.80	95.61	11.63%	32.33%	13.39%
			Post-monsoon	89.96	74.30	82.81			
	S2	Duryai	Pre-monsoon	55.08	63.88	57.24	8.91%	12.40%	16.49%
			Post-monsoon	50.17	55.96	47.80			
	S3	Duryai	Pre-monsoon	40.83	65.06	39.14	10.34%	41.22%	13.11%
			Post-monsoon	36.61	38.24	34.01			
	S4	Talabpur	Pre-monsoon	29.42	29.31	38.76	4.38%	15.22%	13.29%
			Post-monsoon	28.13	24.85	33.61			
Industrial	S5	Bisrakh Road	Pre-monsoon	35.16	39.16	32.12	5.69%	5.85%	16.44%
			Post-monsoon	33.16	36.87	26.84			
	S6	Bisrakh Road	Pre-monsoon	180.40	165.00	201.80	5.65%	3.88%	11.50%
			Post-monsoon	170.20	158.60	178.60			
	S7	Bisrakh Road	Pre-monsoon	140.70	117.80	118.50	3.20%	3.40%	11.22%
			Post-monsoon	136.20	113.80	105.20			
	S8	Bisrakh Road	Pre-monsoon	43.26	49.63	37.44	4.32%	26.42%	12.53%
			Post-monsoon	41.39	36.52	32.75			
	S9	Bisrakh Road	Pre-monsoon	27.75	31.32	28.32	6.59%	15.77%	12.29%
			Post-monsoon	25.92	26.38	24.84			
	S10	Khera Dharampura	Pre-monsoon	50.80	31.19	49.27	19.35%	0.35%	14.27%
			Post-monsoon	40.97	31.08	42.24			
	S11	Bishnuli	Pre-monsoon	122.40	129.60	78.30	15.52%	6.10%	14.28%
			Post-monsoon	103.40	121.70	67.12			
	S12	Achheja	Pre-monsoon	356.10	210.00	223.50	5.87%	2.81%	3.67%
			Post-monsoon	335.20	204.10	215.30			
	S13	Achheja	Pre-monsoon	217.70	198.00	213.90	4.18%	10.15%	12.30%
			Post-monsoon	208.60	177.90	187.60			
	S14	Dujana	Pre-monsoon	17.45	14.61	20.10	19.37%	23.34%	13.68%
			Post-monsoon	14.07	11.20	17.35			
	S15	Dujana	Pre-monsoon	235.40	173.30	215.90	4.89%	0.98%	11.16%
			Post-monsoon	223.90	171.60	191.80			
	S16	Dujana	Pre-monsoon	235.70	234.00	295.90	2.16%	3.72%	13.92%
			Post-monsoon	230.60	225.30	254.70			
	S17	Dujana	Pre-monsoon	213.60	184.80	212.60	1.59%	1.30%	8.28%
			Post-monsoon	210.20	182.40	195.00			
	S18	Badalpur	Pre-monsoon	235.80	210.00	248.00	1.74%	2.00%	13.27%
			Post-monsoon	231.70	205.80	215.10			
Residential	S19	Sadopur	Pre-monsoon	8.52	6.93	6.83	1.48%	7.36%	10.41%
			Post-monsoon	8.39	6.42	6.12			
	S20	Dairy Maccha	Pre-monsoon	150.30	148.80	156.50	22.97%	5.98%	15.21%
			Post-monsoon	115.77	139.90	132.70			
	S21	Dhoom Manikpur	Pre-monsoon	128.54	176.60	181.56	17.19%	9.51%	13.61%
			Post-monsoon	106.45	159.80	156.85			
	S22	Badhpura	Pre-monsoon	310.00	209.40	232.50	22.58%	-0.29%	11.61%
			Post-monsoon	240.00	210.00	205.50			

Table - 5.2.1.16 Statistical Summary of Sodium (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	8.52	Sadopur	8.39	Sadopur	6.93	Sadopur	6.42	Sadopur	6.83	Sadopur	6.12	Sadopur
Max.	356.1	Achheja	335.2	Achheja	234	Dujana	225.3	Dujana	295.9	Dujana	254.7	Dujana
Mean	133.49		121.86		118.10		109.67		126.54		111.54	
St. Dev.	102.28		94.88		76.22		76.19		92.144		82.137	

Higher value of sodium was noted in pre-monsoon samples and decreases in post-monsoon samples. The lower value of sodium in post-monsoon samples is due to recharging of ground aquifers through precipitation. Percent change of sodium from pre-monsoon to post-monsoon season reveals the overall decrease in sodium content of groundwater except at few places. Water quality station at Badhpura in year 2017 show increase in sodium content in post-monsoon sample. Similar type of seasonal variation was recorded by Kumar et al., (2007) in groundwater of Patiala district of Punjab. Lal et al., (2014) reported a sodium concentration range of 51-794 mg/L with mean value of 342 mg/L in groundwater of Bhachau - Kachchh, Gujarat. Effect of seasonal variation on sodium content of groundwater is significant in nature. Mineral dissolution, water-rock interaction, agricultural run-off and sewage effluents enhance the sodium content of groundwater (Sharma & Chhipa, 2016). Sodium levels of ground water can also be increased due to chemicals used for water treatment i.e. sodium fluoride, sodium hypochlorite, sodium bicarbonate etc.

The empirical probability distribution plot of sodium content in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.1.36, 5.2.1.37 and 5.2.1.38 respectively. Box and Whisker plot of sodium in analysed samples showed that data distribution was symmetrical upto a great extent (Fig. 5.2.1.39). Spatial distribution of sodium of groundwater in study area is given in Fig. 5.2.1.40. Distribution map showed high content of sodium in groundwater of industrial area.

BIS has not given any standard concentration for sodium in drinking water. For irrigation water, BIS has recommended the value of sodium percent as 60 and sodium absorption ratio as 10. The WHO has prescribed a taste threshold value of 200 mg/L of sodium for potable water. The taste threshold value of sodium in drinking water depends on the associated anion and the temperature of the aqueous solution. Out of total analysed samples, about 25.8% of samples exceeded the taste threshold value of sodium. These samples were majorly collected from the industrial zone of study area. Only Badhpura water quality station of residential zone has elevated concentration of sodium. The results of analysis indicate that sodium concentration of groundwater of study area was greatly affected by the industrial effluents. Singh & Hussian, (2016) concluded a range of 2.5 to 995.5 mg/L of sodium in groundwater of Greater Noida sub-basin of Uttar Pradesh. Jampani et al., (2018) also analysed the groundwater of Kachiwani Singaram of the Musi river basin adjacent to Hyderabad city and outlined the sodium content of groundwater from 35 to 379 mg/L.

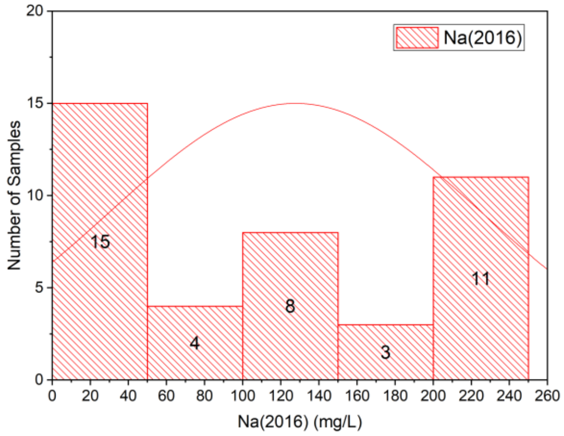


Fig. 5.2.1.36 Empirical probability distribution of Sodium concentration in Groundwater samples (in year 2016)

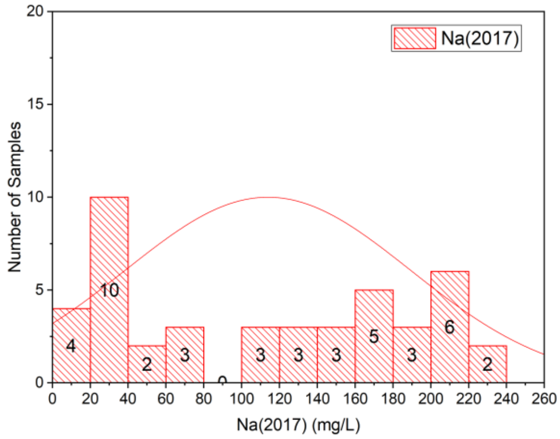


Fig. 5.2.1.37 Empirical probability distribution of Sodium concentration in Groundwater samples (in year 2017)

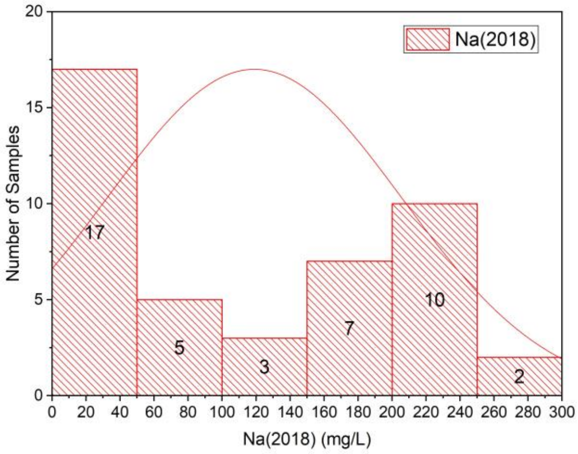


Fig. 5.2.1.38 Empirical probability distribution of Sodium concentration in Groundwater samples (in year 2018)

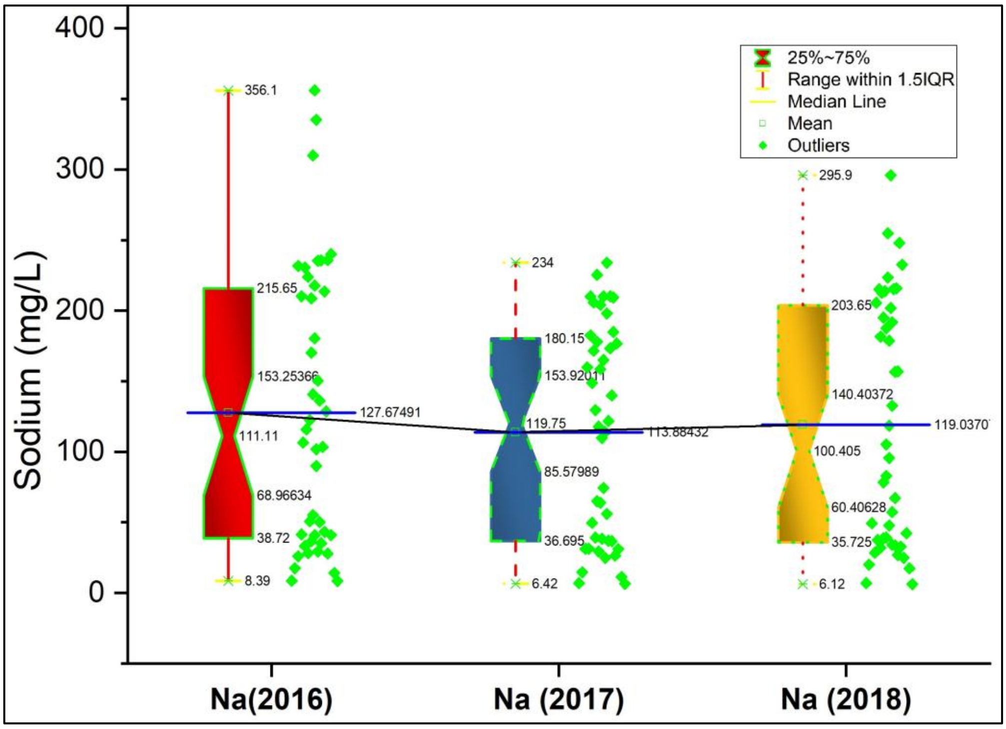
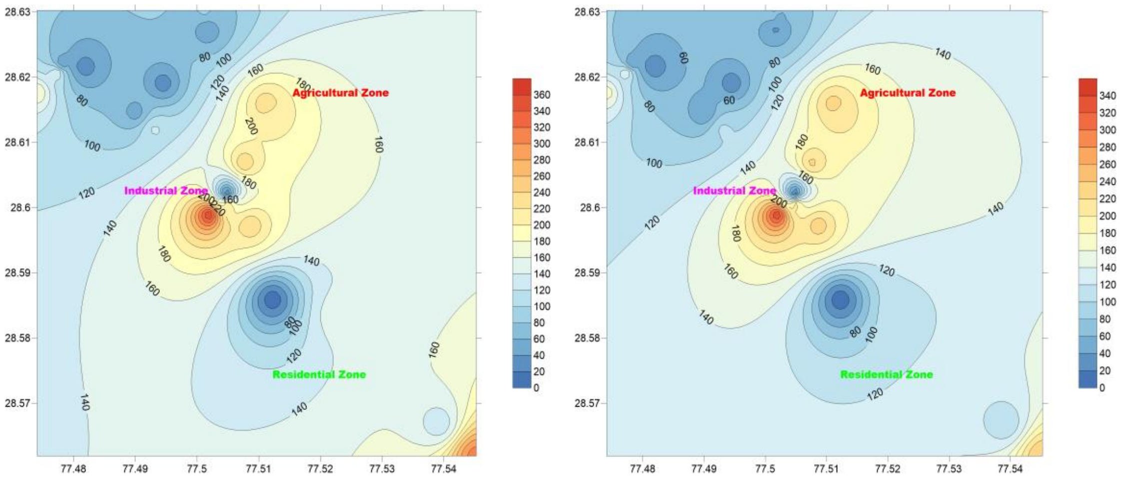
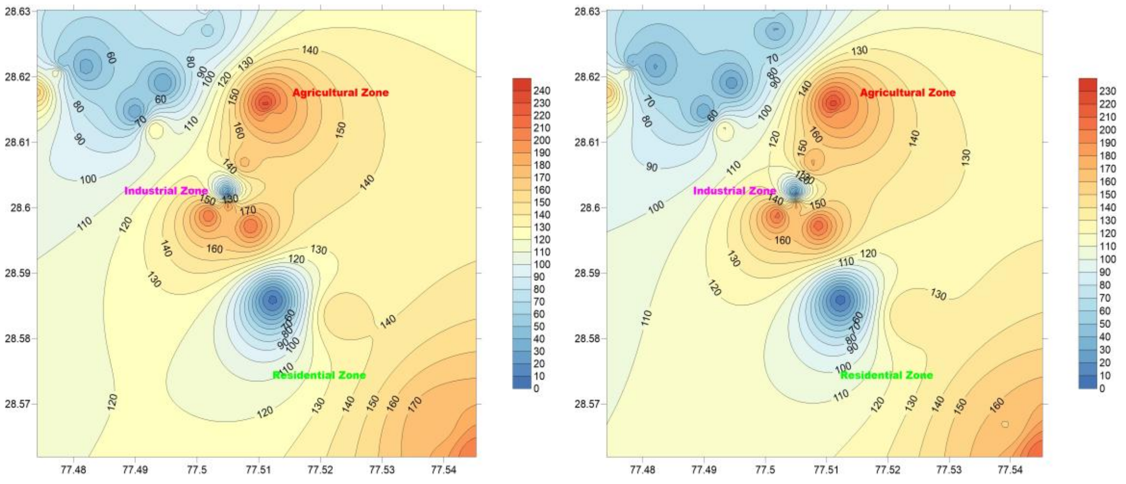


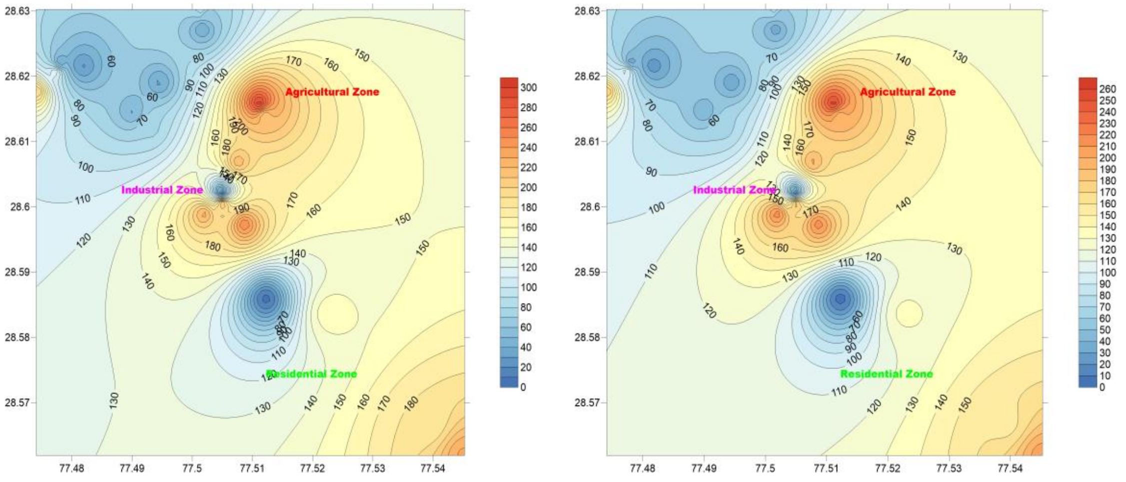
Fig. 5.2.1.39 Box and Whisker plot of Sodium concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.40 Spatial distribution of Sodium in Groundwater samples during study period (2016-2018)

5.2.1.9 Potassium

Potassium is an important element present in water and acts as a key factor in the metabolism of aquatic ecosystem. It also acts as an enzyme activator in living organisms. It is one of the principal ions involved, to assess the quality of water. Potassium ranks seventh in the order of abundance among elements required as a cofactor for as many as over forty enzymes and it has an important role in stomatal movement. It also maintains electroneutrality in plant cells. Potassium content of groundwater remains quite low than that of other major cations. Naturally potassium enters to ground aquifers due to weathering of the rocks but the concentration increases due to the addition of polluted water rich in potassium. Potassium also enters the exchange equilibrium of the absorbed cation. In small quantity, potassium has no adverse impact on human health but when present in large quantities it may act as laxative.

Potassium is an important cation occurring in all kinds of water. Sodium and potassium are closely related to each other. The presence of potassium is less wide spread in nature for which it is found at low concentration than sodium. Potassium occurs in rain water upto 0.1 mg/L and up to a few ppm in surface waters. High value of potassium indicates man-made pollution.

The results of the water quality analysis with respect to potassium at all the twenty-two water quality stations of the study area are shown in Table - 5.2.1.17 and 5.2.1.18.

In the current study the potassium content in groundwater varied from 3.26 to 62.5 mg/L with a mean value of 23.69 mg/L. The minimum value of 3.26 mg/L was recorded from post-monsoon samples of Dairy Maccha water quality station in year 2016 whereas the maximum value of 62.5 mg/L was recorded from pre-monsoon samples of Badhpura water quality station in the same year. In year 2016, the sample collected in pre-monsoon season from Badhpura water quality station showed a peak value (62.5 mg/L) of potassium and minimum value of 3.26 mg/L of potassium was shown by groundwater samples of Dairy Maccha water quality station, with a mean value of 24.97 ± 17.92 mg/L. In year 2017 groundwater samples showed a rise in the minimum value of potassium. The range of potassium in year 2017 was 4.48 to 51.0 mg/L with a mean value of 21.29 ± 16.37 mg/L. The minimum concentration of potassium was at Sadopur and maximum was at Badalpur water quality station. In year 2018, highest potassium was at Badalpur water quality station (54.49 mg/L) and lowest at Sadopur water quality station (5.19 mg/L). In whole study period Badalpur water quality station always showed elevated concentration of potassium in groundwater.

Table - 5.2.1.17 Seasonal Variation in Potassium concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	18.67	11.27	20.62	2.68%	-30.61%	10.57%
			Post-monsoon	18.17	14.72	18.44			
	S2	Duryai	Pre-monsoon	7.82	6.28	6.88	-4.21%	1.91%	10.84%
			Post-monsoon	8.15	6.16	6.14			
	S3	Duryai	Pre-monsoon	10.87	6.68	11.84	6.53%	-55.09%	5.41%
			Post-monsoon	10.16	10.36	11.20			
	S4	Talabpur	Pre-monsoon	19.01	17.34	32.98	4.63%	-8.07%	11.22%
			Post-monsoon	18.13	18.74	29.28			
Industrial	S5	Bisrakh Road	Pre-monsoon	5.95	5.43	8.73	3.98%	1.10%	5.04%
			Post-monsoon	5.71	5.37	8.29			
	S6	Bisrakh Road	Pre-monsoon	34.97	32	37.94	3.40%	6.03%	13.31%
			Post-monsoon	33.78	30.07	32.89			
	S7	Bisrakh Road	Pre-monsoon	38.48	32.3	34.75	3.61%	0.53%	5.44%
			Post-monsoon	37.09	32.13	32.86			
	S8	Bisrakh Road	Pre-monsoon	15.06	7.6	18.10	1.26%	-95.00%	2.93%
			Post-monsoon	14.87	14.82	17.57			
	S9	Bisrakh Road	Pre-monsoon	16.84	6.41	11.48	3.56%	0.19%	12.02%
			Post-monsoon	16.24	6.398	10.10			
	S10	Khera Dharampura	Pre-monsoon	11.41	9.5	13.12	7.36%	3.26%	4.65%
			Post-monsoon	10.57	9.19	12.51			
	S11	Bishnuli	Pre-monsoon	10.86	7.22	18.05	6.81%	0.42%	1.94%
			Post-monsoon	10.12	7.19	17.70			
	S12	Achheja	Pre-monsoon	48.43	27.9	31.45	4.81%	1.47%	0.38%
			Post-monsoon	46.10	27.49	31.33			
	S13	Achheja	Pre-monsoon	35.89	32.78	35.64	6.55%	7.32%	9.88%
			Post-monsoon	33.54	30.38	32.12			
	S14	Dujana	Pre-monsoon	10.17	5.98	11.92	7.05%	2.31%	1.59%
			Post-monsoon	9.46	5.842	11.73			
	S15	Dujana	Pre-monsoon	58.27	47.13	48.23	10.09%	10.25%	13.97%
			Post-monsoon	52.39	42.3	41.49			
	S16	Dujana	Pre-monsoon	44.35	45	54.15	3.31%	7.11%	14.83%
			Post-monsoon	42.88	41.8	46.12			
	S17	Dujana	Pre-monsoon	48.34	49.1	51.60	3.35%	3.91%	16.88%
			Post-monsoon	46.72	47.18	42.89			
	S18	Badalpur	Pre-monsoon	49.18	51	54.49	10.07%	6.96%	13.34%
			Post-monsoon	44.23	47.45	47.22			
Residential	S19	Sadopur	Pre-monsoon	6.23	4.97	5.29	0.27%	9.90%	1.91%
			Post-monsoon	6.21	4.478	5.19			
	S20	Dairy Maccha	Pre-monsoon	6.52	6.96	7.86	50.00%	4.45%	2.55%
			Post-monsoon	3.26	6.65	7.66			
	S21	Dhoom Manikpur	Pre-monsoon	9.79	12.65	13.45	-1.02%	19.76%	13.83%
			Post-monsoon	9.89	10.15	11.59			
	S22	Badhpura	Pre-monsoon	62.50	45.45	53.68	18.08%	-3.08%	33.87%
			Post-monsoon	51.20	46.85	35.50			

Table - 5.2.1.18 Statistical Summary of Potassium (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	5.95	Bisrakh Road	3.26	Dairy Maccha	4.97	Sadopur	4.48	Sadopur	5.29	Sadopur	5.19	Sadopur
Max.	62.5	Badhpura	52.39	Dujana	51.0	Badalpur	47.45	Badalpur	54.49	Badalpur	47.22	Badalpur
Mean	25.89		24.04		21.41		21.17		26.47		23.173	
St. Dev.	18.99		17.17		17.20		15.89		17.478		14.152	

When agricultural zone was taken into consideration, the minimum and maximum values for potassium cocentration were 6.14 (in post-monsoon sample of 2018 from Duryai) and 32.98 mg/L (in pre-monsoon sample of 2018 from Talabpur) with a mean value of 14.16 mg/L whereas in industrial zone, potassium concentration ranged between 5.37 (in post-monsoon sample of 2017 from Bisrakh Road) and 58.27 mg/L (in pre-monsoon sample of 2016 from Dujana). Residential zone of study area also has a wide range of potassium concentration with a minimum value of 3.26 mg/L and a maximum value of 62.5 mg/L. The mean value of potassium in three different zone was in order; Industrial (28.02 mg/L) > Residential (18.08 mg/L) > Agricultural (14.16 mg/L). The results indicate the addition of potassium containing industrial wastes into ground aquifers. Similar types of results were also reported by many researchers (Kumar et al., 2007; Ranjana, 2010; Jampani et al., 2018).

Percent change of potassium from pre-monsoon to post-monsoon season reveals that there was a significant effect of precipitation on potassium concentration of groundwater. In year 2016 and 2018, a decrease in potassium content of groundwater was observed in post-monsoon samples. But in year 2017, potassium concentration increase in post-monsoon samples. This exceptional increase is due to leaching of potassium rich water through soil layers.

The empirical probability distribution plot of potassium in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.1.41, 5.2.1.42 and 5.2.1.43 respectively. Box and Whisker plot was also drawn to know the distributional characterstics of potassium values of groundwater during study period (Fig. 5.2.1.44). Spatial distribution of potassium in analysed groundwater samples is given in Fig. 5.2.1.45. Analysis of various plots revealed that most of the samples have potassium concentration below 20 mg/L. High content of potassium was obtained from samples of industrial zone.

BIS and WHO does not give any health based guideline value for potassium because it is an essential metal for humans. The daily human requirement of potassium is greater than 3000 mg. Even after the treatment of water with potassium permanganate in the municipal supply, its concentration is far below to have any significant health impacts. In some countries, the softening of water is done by using potassium chloride (Wist et al., 2009). This results into a slight increase in the concentration of potassium in water. The consumption of this potassium rich water can affect the health of high risks group (i.e. people suffering from kidney related issues, heart problem, coronary artery disease etc.). Such individuals are advised not to consume water rich in potassium. Lal et al., (2014) analysed the grounwater samples of Bhachau taluka in Kachchh district of Gujarat and reported a mean value of 14 mg/L of potassium. Singh & Hussian (2016) have done a similar type of analysis in the vicinity of Greater Noida

sub-basin.

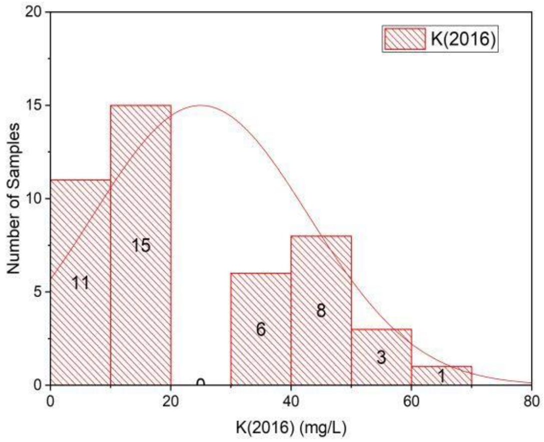


Fig. 5.2.1.41 Empirical probability distribution of Potassium concentration in Groundwater samples (in year 2016)

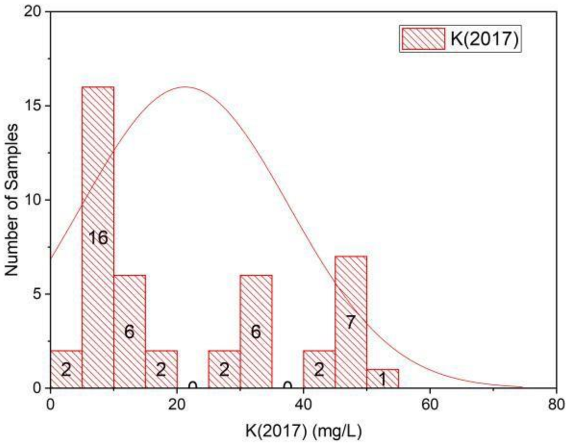


Fig. 5.2.1.42 Empirical probability distribution of Potassium concentration in Groundwater samples (in year 2017)

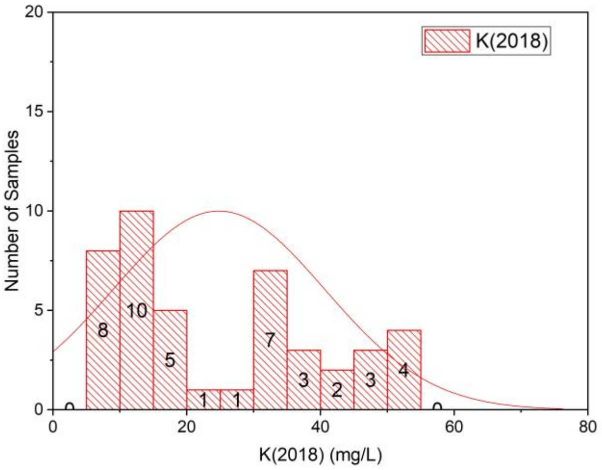


Fig. 5.2.1.43 Empirical probability distribution of Potassium concentration in Groundwater samples (in year 2018)

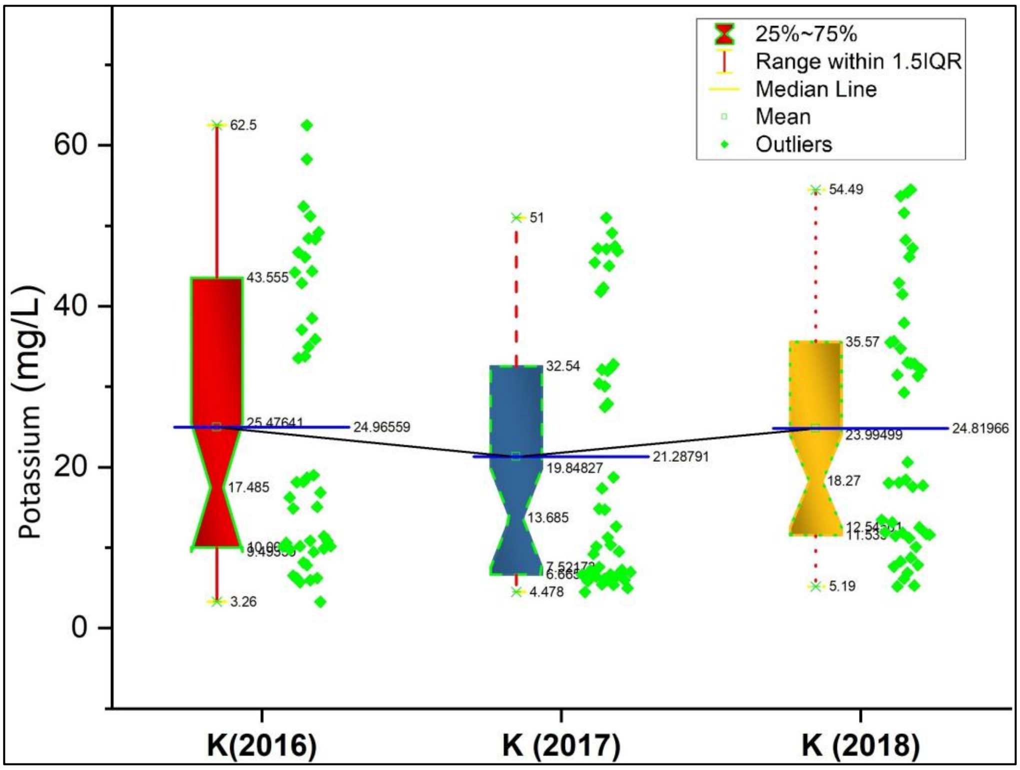
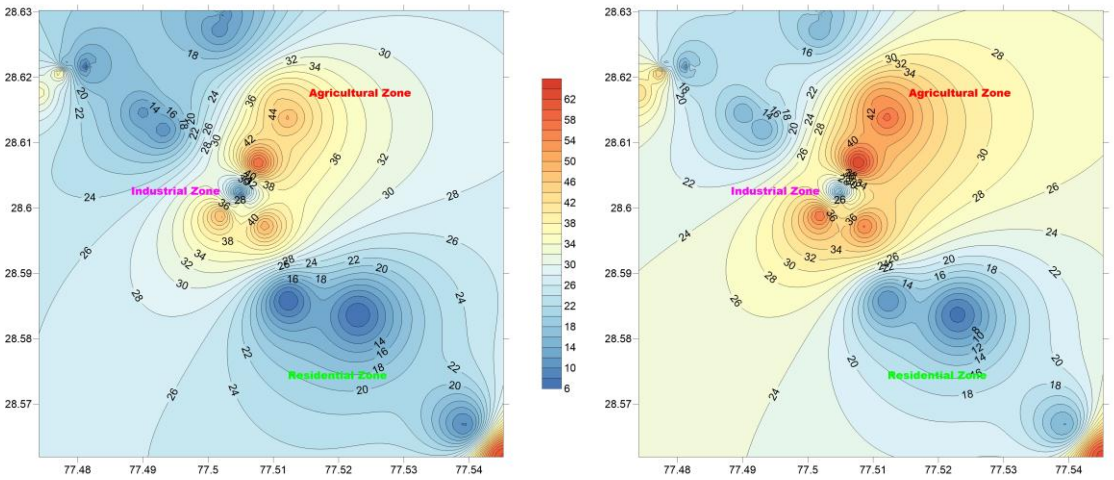
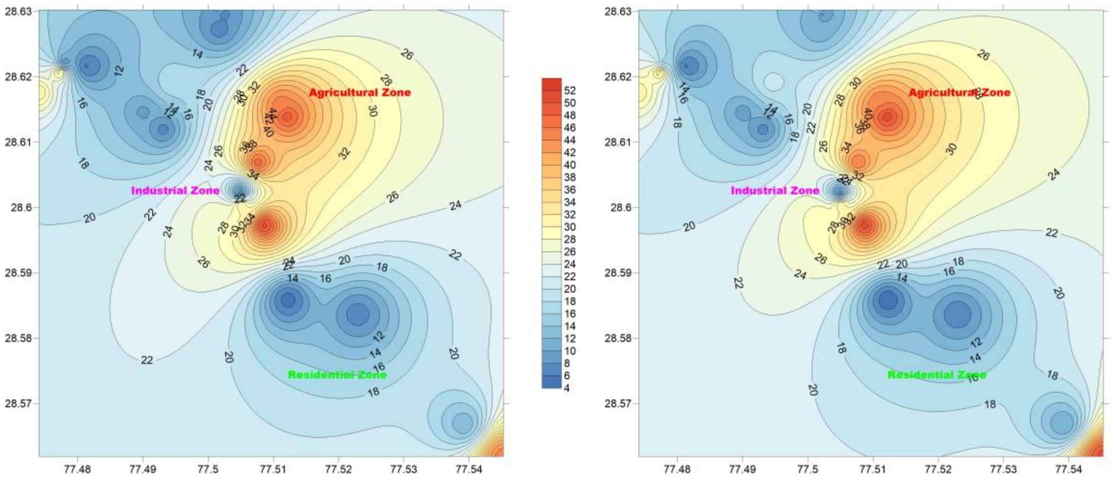


Fig. 5.2.1.44 Box and Whisker plot of Potassium concentration in Groundwater samples during study period (2016-2018)



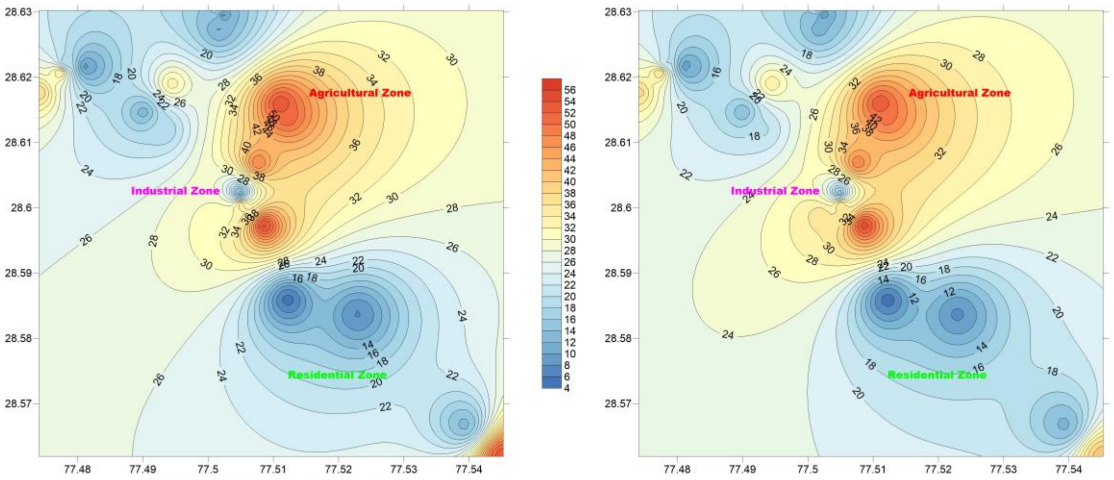
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.45 Spatial distribution of Potassium in Groundwater samples during study period (2016-2018)

5.2.1.10 Boron

The mean abundance of boron varied widely in different sphere of environment. It is 9 ppm in earth's crust, 18 to 63 ppm in soils, 10 µg/L in streams, and 0.001 to 10 mg/L in groundwater. Boron is naturally present in groundwater due to weathring of borosilicates minerals containing rocks. Boron content of groundwater can be increased due to leaching of borax present in industrial effluents of glass, soap and detergent manufacturing industries.

At acidic pH, boron is commonly present in water bodies in the form of boric acid. At alkaline pH, it is present in the form of meta-borate anion and near to neutral pH, water soluble poly borate anions [$B_3O_3(OH)_4^-$, $B_4O_5(OH)_4^-$, and $B_5O_6(OH)_4^-$] are major species.

Boron is essential for natural growth of plants but high content of boron in irrigation water causes boron toxicity. The occurrence of boron in less than 0.1 mg/L concentration, is harmless to human health. High concentration of boron (> than 1 mg/L) is rarely obtained in drinking water. Marine water contains relatively higher amount of boron (5 mg/L) in the form of boric acid. Boron is a contributor to the buffer capacity of the ocean and other natural waters.

Boron content of drinking water depends upon the source of water. Generally its concentration in drinking water varied from 0.1 to 0.3 mg/L. Intake of large amount of boron causes disorders in central nervous system. According to Stokinger, (1981) 5 to 20 gm of boric acid is fatal for adults and a dose of less than 5 gm is fatal for infants. However from a study made by Litovitz, (1988), the range of letal dose of boron for adults is 15 to 20 gm and 3 to 6 gm for infants.

Table - 5.2.1.19 and 5.2.1.20 represents the results of boron analysis.

The analytical results of boron analysis during study period ranged from 0.191 to 3.14 mg/L. Its minimum value was obtained from post-monsoon samples of year 2016 at Dhoom Manikpur water quality station and maximum value was found in groundwater samples of pre-monsoon season of year 2016 at Duryai station with a mean value of 1.041 mg/L. WHO gives a guideline value of 2.4 mg/L of boron in safe drinking water. BIS put forward an acceptable limit of boron in drinking water 0.5 mg/L and a permissible limit of 1 mg/L in absence of alternative source of drinking water. Mean concentration of boron in groundwater of study area was below the guideline value of WHO but above the acceptable limit of BIS.

Table - 5.2.1.19 Seasonal Variation in Boron concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	3.140	1.980	2.080	6.37%	11.62%	8.65%
			Post-monsoon	2.940	1.750	1.900			
	S2	Duryai	Pre-monsoon	1.830	1.560	2.100	-18.03%	-67.31%	11.43%
			Post-monsoon	2.160	2.610	1.860			
	S3	Duryai	Pre-monsoon	1.020	0.827	1.072	9.00%	-17.85%	13.00%
			Post-monsoon	0.928	0.975	0.933			
	S4	Talabpur	Pre-monsoon	2.670	2.690	2.410	20.22%	29.00%	12.03%
			Post-monsoon	2.130	1.910	2.120			
Industrial	S5	Bisrakh Road	Pre-monsoon	1.080	0.931	0.837	3.70%	2.04%	0.96%
			Post-monsoon	1.040	0.912	0.829			
	S6	Bisrakh Road	Pre-monsoon	0.468	0.613	0.642	16.88%	-16.80%	7.94%
			Post-monsoon	0.389	0.716	0.591			
	S7	Bisrakh Road	Pre-monsoon	1.340	1.790	1.460	9.70%	36.31%	18.49%
			Post-monsoon	1.210	1.140	1.190			
	S8	Bisrakh Road	Pre-monsoon	1.030	1.460	1.580	-1.94%	17.81%	9.49%
			Post-monsoon	1.050	1.200	1.430			
	S9	Bisrakh Road	Pre-monsoon	0.892	1.100	1.150	12.00%	-1.82%	6.96%
			Post-monsoon	0.785	1.120	1.070			
	S10	Khera Dharampura	Pre-monsoon	1.120	1.320	0.910	2.68%	26.52%	8.57%
			Post-monsoon	1.090	0.970	0.832			
	S11	Bishnuli	Pre-monsoon	0.883	0.812	0.869	5.21%	4.43%	13.00%
			Post-monsoon	0.837	0.776	0.756			
	S12	Achheja	Pre-monsoon	0.671	0.831	0.689	-10.58%	5.17%	-20.75%
			Post-monsoon	0.742	0.788	0.832			
	S13	Achheja	Pre-monsoon	0.654	0.932	1.080	-15.60%	6.44%	17.50%
			Post-monsoon	0.756	0.872	0.891			
	S14	Dujana	Pre-monsoon	0.992	1.150	1.884	10.00%	9.00%	13.00%
			Post-monsoon	0.893	1.047	1.639			
	S15	Dujana	Pre-monsoon	0.884	0.994	1.050	10.00%	18.11%	5.14%
			Post-monsoon	0.796	0.814	0.996			
	S16	Dujana	Pre-monsoon	1.100	1.130	1.351	1.82%	8.00%	13.00%
			Post-monsoon	1.080	1.040	1.176			
	S17	Dujana	Pre-monsoon	0.861	0.913	1.050	9.64%	3.40%	14.10%
			Post-monsoon	0.778	0.882	0.902			
	S18	Badalpur	Pre-monsoon	1.170	0.872	0.911	8.55%	1.95%	1.10%
			Post-monsoon	1.070	0.855	0.901			
Residential	S19	Sadopur	Pre-monsoon	0.324	0.341	0.313	7.72%	0.29%	1.92%
			Post-monsoon	0.299	0.340	0.307			
	S20	Dairy Maccha	Pre-monsoon	0.567	0.412	0.554	2.29%	0.73%	2.35%
			Post-monsoon	0.554	0.409	0.541			
	S21	Dhoom Manikpur	Pre-monsoon	0.214	0.223	0.312	10.75%	4.48%	4.49%
			Post-monsoon	0.191	0.213	0.298			
	S22	Badhpura	Pre-monsoon	0.320	0.450	0.351	-62.50%	42.22%	11.11%
			Post-monsoon	0.520	0.260	0.312			

Table-5.2.1.20 Statistical Summary of Boron (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.214	Dhoom Manikpur	0.191	Dhoom Manikpur	0.223	Dhoom Manikpur	0.213	Dhoom Manikpur	0.312	Dhoom Manikpur	0.298	Dhoom Manikpur
Max.	3.14	Duryai	2.94	Duryai	2.69	Talabpur	2.61	Duryai	2.41	Talabpur	2.12	Talabpur
Mean	1.06		1.01		1.06		0.98		1.121		1.014	
St. Dev.	0.71		0.64		0.58		0.55		0.593		0.5104	

During 2016, boron concentration ranged from 0.191 to 3.14 with a mean of 1.03 ± 0.67 mg/L. In year 2017, the base value (0.213 mg/L) was obtained from Dhoom Manikpur station and maximum value (2.69 mg/L) was obtained from Talabpur station. The range of boron, in year 2018 was 0.298 to 2.41 with a mean of 1.067 mg/L. During study period the maximum mean value was in year 2018.

In agricultural zone of study area, boron concentration was found from 0.827 mg/L (in 2017 at Duryai station) to 3.14 mg/L (in 2016 at Duryai station). In industrial zone, it ranged from 0.389 mg/L (In 2016 at Bisrakh Road) to 1.884 mg/L (in 2018 at Dujana). Residential zone showed a range of boron concentration 0.191 mg/L to 0.567 mg/L. The decreasing order of mean value of boron was 1.9 mg/L (agricultural zone) > 0.99 mg/L (industrial zone) > 0.359 mg/L (residential zone).

The empirical probability distribution plots with respect to boron at all the twenty-two water quality stations of the study area during study period (2016, 2017 & 2018) are shown in Fig. 5.2.1.46, 5.2.1.47 and 5.2.1.48 respectively. Most of the analyzed samples were in the range of 0.5 to 1.5 mg/L of boron concentration. Box and Whisker plot of boron in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.1.49. The GIS maps for boron of groundwater in study area is presented in Fig. 5.2.1.50. The boron concentration of groundwater depends upon the geology of the area and wastewater discharge in that area.

Out of total analysed samples nearly 84% of samples exceeded the acceptable limit and 42.42% of samples were beyond the permissible limit of boron given by BIS. Kumar et al., (2017) documented a range of groundwater boron conentration from

0.239 to 9.304 mg/L in industrial area of Gautam Buddha Nagar in Uttar Pradesh. Kumar et al., (2019) reported that 46% of analysed samples of Saharanpur district of Uttar Pradesh had boron content higher than 1 mg/L and 3% of samples exceeded the standard value of WHO. Laboratory experiments were done on rats, mice and dogs to know the toxicity of boron and results indicate that male reproductive tract is target organ of boron toxicity (WHO 2017).

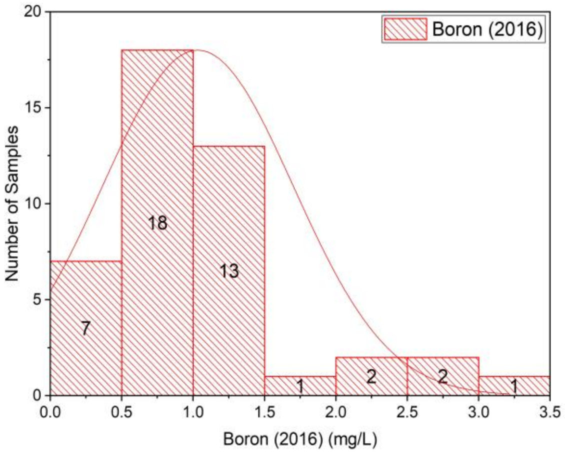


Fig. 5.2.1.46 Empirical probability distribution of Boron concentration in Groundwater samples (in year 2016)

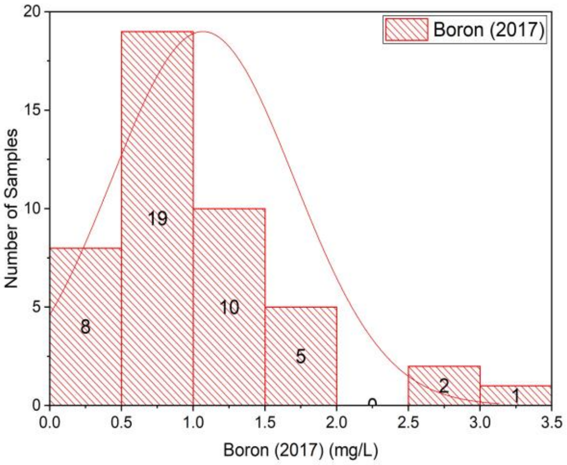


Fig. 5.2.1.47 Empirical probability distribution of Boron concentration in Groundwater samples (in year 2017)

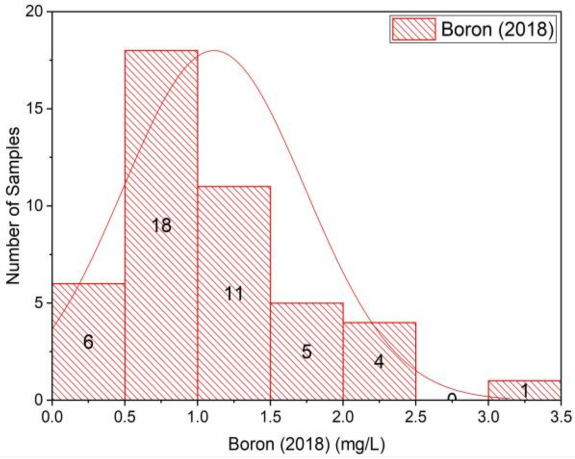


Fig. 5.2.1.48 Empirical probability distribution of Boron concentration in Groundwater samples (in year 2018)

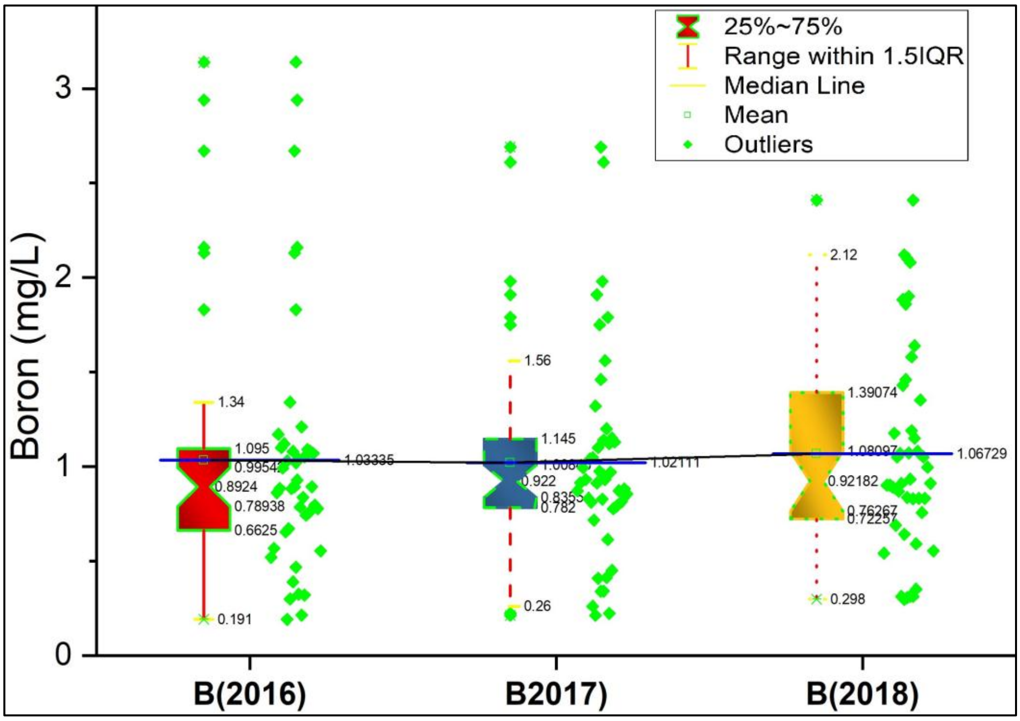
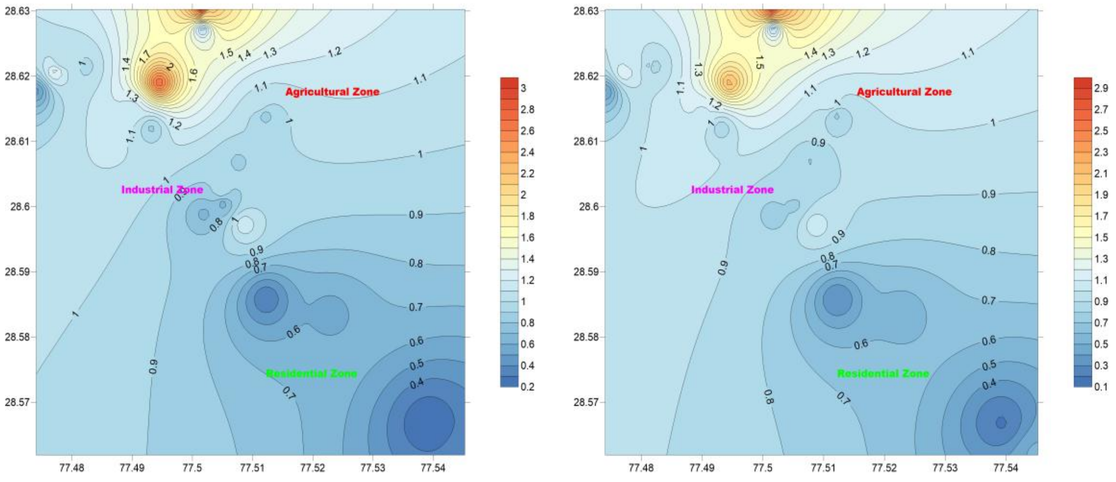
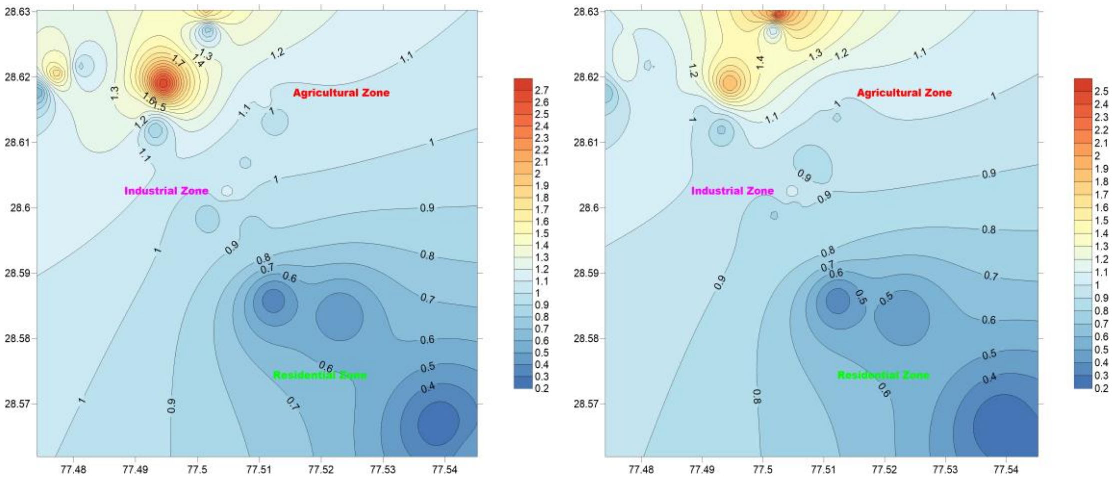


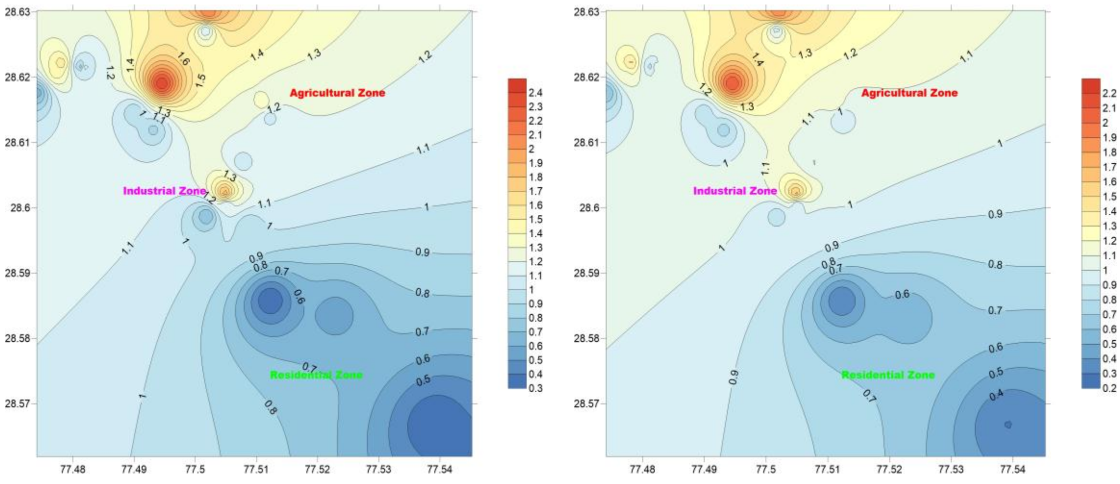
Fig. 5.2.1.49 Box and Whisker plot of Boron concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.50 Spatial distribution of Boron in Groundwater samples during study period (2016-2018)

5.2.1.11 Total Alkalinity (TA)

The buffering capacity of water which refers to the quantity and kind of dissolved compounds that collectively shift the pH to the alkaline side is known as total alkalinity. All cations associated with weak base (bicarbonate, carbonate, organic acids) and hydroxyl ions belong to this category. The degree of alkalinity of water is measured by the volume of the strong acid solution required to neutralize it. In unpolluted natural water, alkalinity is chiefly due to occurrence of bicarbonate of alkaline earth metals. The alkalinity of water has little public health significance as it is not harmful to human neings, but alkalinity beyond 200 mg/L gives unpleasant taste to the water. Alkalinity is significant in many uses of water and for water treatment. Alkalinity of water in the presence of excess alkaline earth metal is significant in deciding its suitability for irrigation.

Table – 5.2.1.21 and 5.2.1.22 represents the alkalinity value of groundwater of study area.

Total alkalinity of groundwater of study area was recorded from 87.67 to 683.33 mg/L with a mean value of 251.18 mg/L. It was recorded maximum in pre-monsoon sample of 2016 at Badhpura water quality station and minimum at Bisrakh Road water quality station in post-monsoon sample of 2018. BIS put forwards 200 mg/L as an acceptable value and 600 mg/L as permissible value of alkalinity in potable water. The mean value of total alkalinity (251.18 mg/L) during study period was higher than the desirable level of alkalinity given by BIS. During 2016 the variation in total alkalinity in the study area was from 99.83 mg/L (in post-monsoon at Bisrakh Road) to 683.33 mg/L(in pre-monsoon at Badhpura) while, in 2017 it ranged from a minimum of 98.92 mg/L (in post-monsoon of Bisrakh Road) to a maximum of 531.08 mg/L (in pre-monsoon of Dhoom Manikpur). It was observed that values ranged from 87.67 mg/L (in post-monsoon of Bisrakh Road) to 621 mg/L (in pre-monsoon of Badhpura) during 2018. The mean value of total alkalinity during study period was maximum in year 2016 (259.28 ± 130.48 mg/L) and minimum in year 2017 (236.29 ± 109.32 mg/L). In 2018, its mean value was 257.97 ± 128.22 mg/L.

Phenolphthalein alkalinity was also recorded in few samples of study area-Bisrakh Road, Dujana and Badalpur water quality station. It ranged from 8.73 to 42.71 mg/L with a mean value of 18.23 mg/L.

Table – 5.2.1.21 Seasonal Variation in Total Alkalinity (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	208.67	193.75	197.00	8.79%	11.44%	13.41%
			Post-monsoon	190.33	171.58	170.58			
	S2	Duryai	Pre-monsoon	197.83	190.67	196.00	9.10%	4.41%	12.24%
			Post-monsoon	179.83	182.25	172.00			
	S3	Duryai	Pre-monsoon	204.75	208.08	203.83	8.18%	7.53%	12.84%
			Post-monsoon	188.00	192.42	177.67			
	S4	Talabpur	Pre-monsoon	170.67	154.92	233.67	2.29%	6.08%	12.55%
			Post-monsoon	166.75	145.50	204.33			
Industrial	S5	Bisrakh Road	Pre-monsoon	101.33	104.75	100.50	1.48%	4.46%	12.77%
			Post-monsoon	99.83	100.08	87.67			
	S6	Bisrakh Road	Pre-monsoon	267.25	240.83	310.58	5.49%	1.11%	8.53%
			Post-monsoon	252.58	238.17	284.08			
	S7	Bisrakh Road	Pre-monsoon	243.83	202.03	194.43	3.12%	5.74%	12.90%
			Post-monsoon	236.22	190.43	169.35			
	S8	Bisrakh Road	Pre-monsoon	157.42	153.00	150.75	2.33%	8.71%	13.38%
			Post-monsoon	153.75	139.67	130.58			
	S9	Bisrakh Road	Pre-monsoon	110.58	108.00	105.33	2.19%	8.41%	14.16%
			Post-monsoon	108.17	98.92	90.42			
	S10	Khera Dharampura	Pre-monsoon	267.67	230.25	266.25	10.37%	10.64%	14.62%
			Post-monsoon	239.92	205.75	227.33			
	S11	Bishnuli	Pre-monsoon	300.92	290.42	279.17	5.43%	3.67%	13.61%
			Post-monsoon	284.58	279.75	241.17			
	S12	Achheja	Pre-monsoon	483.17	283.33	306.75	4.83%	1.82%	3.34%
			Post-monsoon	459.83	278.17	296.50			
	S13	Achheja	Pre-monsoon	336.33	305.00	299.50	3.69%	9.51%	11.38%
			Post-monsoon	323.92	276.00	265.42			
	S14	Dujana	Pre-monsoon	182.83	141.25	227.83	9.57%	10.09%	12.80%
			Post-monsoon	165.33	127.00	198.67			
	S15	Dujana	Pre-monsoon	346.85	257.82	309.58	9.45%	9.43%	13.11%
			Post-monsoon	314.08	233.52	269.00			
	S16	Dujana	Pre-monsoon	450.80	456.67	544.00	2.82%	8.18%	12.70%
			Post-monsoon	438.08	419.33	474.90			
	S17	Dujana	Pre-monsoon	227.97	220.17	238.25	3.25%	4.31%	4.04%
			Post-monsoon	220.57	210.68	228.63			
	S18	Badalpur	Pre-monsoon	252.70	251.67	305.02	-0.11%	0.00%	0.63%
			Post-monsoon	252.97	251.67	303.10			
Residential	S19	Sadopur	Pre-monsoon	171.08	145.33	146.33	0.83%	2.06%	10.65%
			Post-monsoon	169.67	142.33	130.75			
	S20	Dairy Maccha	Pre-monsoon	131.33	214.83	237.25	5.14%	1.26%	12.00%
			Post-monsoon	124.58	212.13	208.78			
	S21	Dhoom Manikpur	Pre-monsoon	398.33	531.08	548.08	13.71%	14.00%	22.05%
			Post-monsoon	343.71	456.73	427.22			
	S22	Badhpura	Pre-monsoon	683.33	500.67	621.00	12.20%	8.12%	8.00%
			Post-monsoon	600.00	460.00	571.32			

Table – 5.2.1.22 Statistical Summary of Total Alkalinity (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	101.33	Bisrakh Road	99.83	Bisrakh Road	104.75	Bisrakh Road	98.92	Bisrakh Road	100.5	Bisrakh Road	87.66	Bisrakh Road
Max.	683.33	Badhpura	600	Badhpura	531.08	Dhoom Manikpur	460	Badhpura	621	Badhpura	571.32	Badhpura
Mean	267.98		250.58		244.75		227.82		273.69		242.24	
St. Dev.	138.98		124.05		116.62		103.54		136.886		120.029	

In agricultural zone total alkalinity ranged from 145.50 to 233.67 mg/L with a mean value of 187.55 mg/L. The total alkalinity in industrial zone ranged between 87.67 and 544 mg/L providing a mean value of 243.79 mg/L. Residential zone of study area also has a wide range of total alkalinity with a minimum value of 124.58 mg/L and a maximum value of 683.33 mg/L with a mean of 340.66 mg/L. In residential zone, Dairy Maccha station showed minimum alkalinity and Badhpura station showed maximum alkalinity in groundwater. The mean value of total alkalinity was maximum in residential zone of study area. The increasing order of mean total alkalinity in three zones was; agricultural < industrial < residential.

Percent change in total alkalinity value from pre-monsoon to post-monsoon season revealed that dilution of groundwater was prevalent in study area. Similar types of results were obtained by many researchers (Ibraheem et al., 2015, Nasir et al., 2017, Jampani et al., 2018, Kammoun et al., 2018). Chabukdhara et al., (2017) analysed the groundwater quality in the peri-urban and urban industrial clusters of Ghaziabad and reported range of total alkalinity from 148 to 820 mg/L (in pre-monsoon season) and 122 to 717 mg/L (in post-monsoon season). They stated that mean value of total alkalinity decreased from 370 mg/L (in pre-monsoon season) to 302 mg/L in post-monsoon season.

The empirical probability distribution plots of TA in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.1.51, 5.2.1.52 and 5.2.1.53 respectively. Plot showed that maximum number of samples have TA value between 100 and 200 mg/L in year 2016, but in year 2017 and 2018, majority of samples fall in the category of 200 to 300 mg/L of TA. Box and Whisker plot was also drawn to know the distributional characterstics of TA values of groundwater during study period (Fig. 5.2.1.54). Spatial distribution map of total alkalinity of groundwater in study area also showed relative level of it, at studied water quality stations (Fig. 5.2.1.55).

Although alkalinity of water does not have any health hazards but highly alkaline water is not good for health and irrigation purpose. Out of total analysed samples, 60.6% of samples have total alkalinity above the desirable limit of BIS. Two samples collected from Badhpura water quality station in pre-monsoon season of year 2016 & 2018 exceeded the permissible limit of BIS. Presence of higher alkalinity in groundwater indicates anthropogenic source of it (Selvakumar et al., 2017).

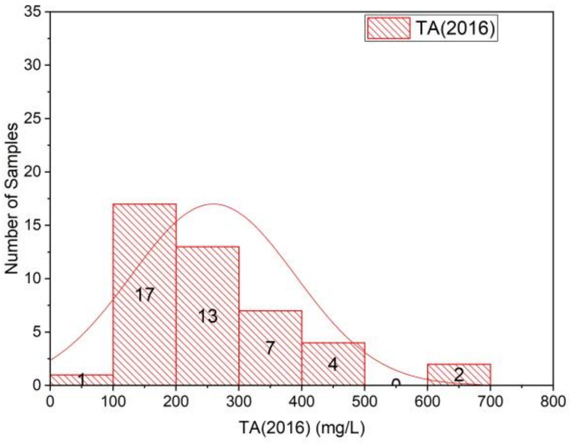


Fig. 5.2.1.51 Empirical probability distribution of Total Alkalinity in Groundwater samples (in year 2016)

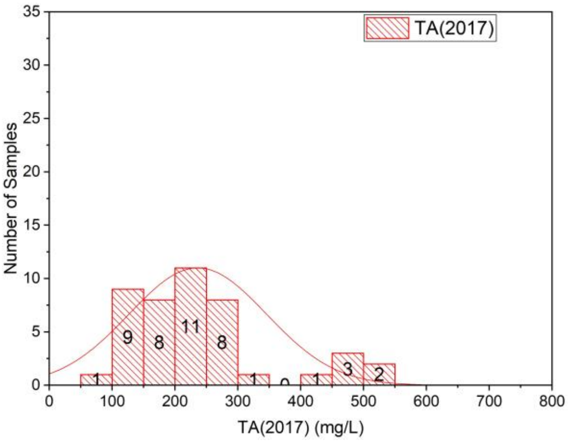


Fig. 5.2.1.52 Empirical probability distribution of Total Alkalinity in Groundwater samples (in year 2017)

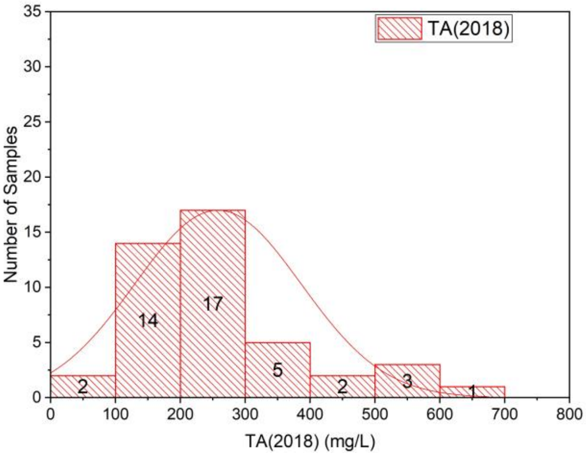


Fig. 5.2.1.53 Empirical probability distribution of Total Alkalinity in Groundwater samples

(in year 2018)

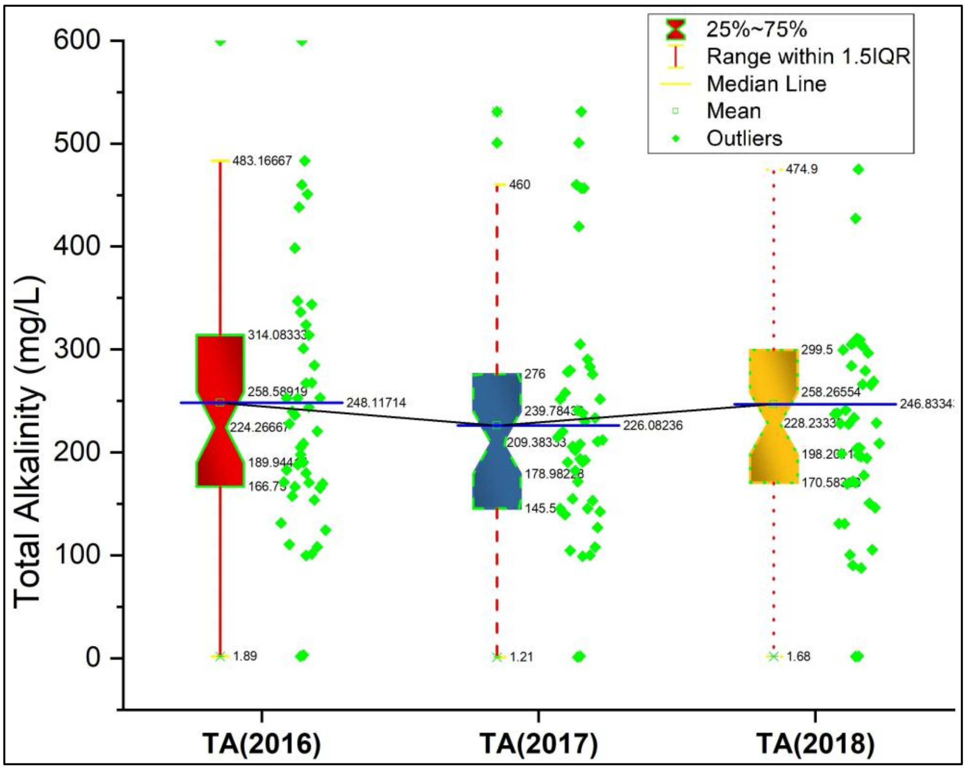
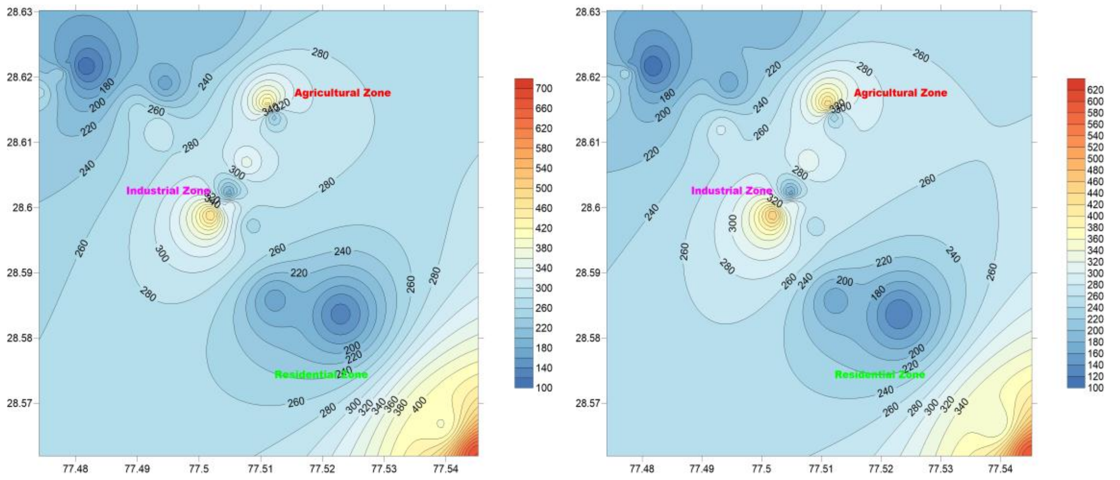
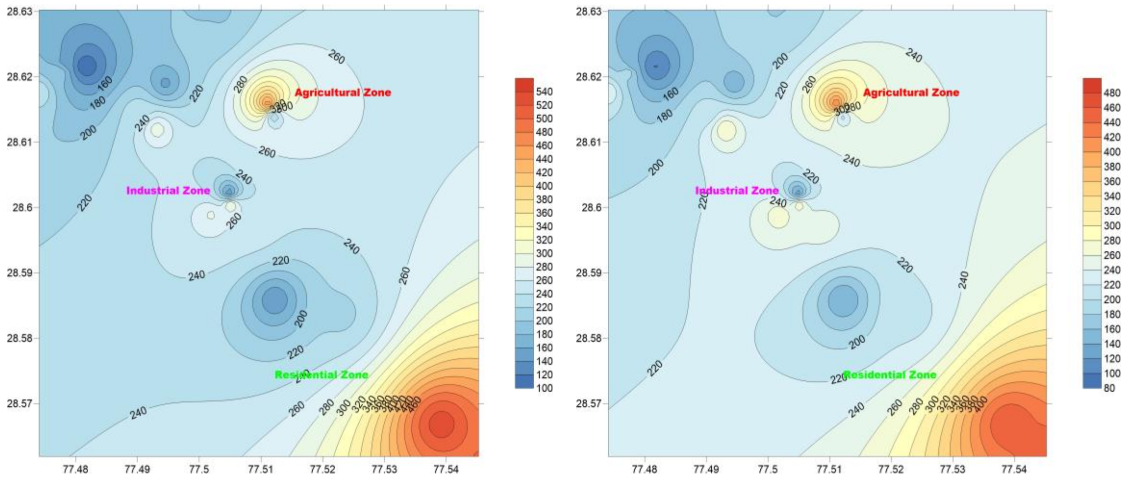


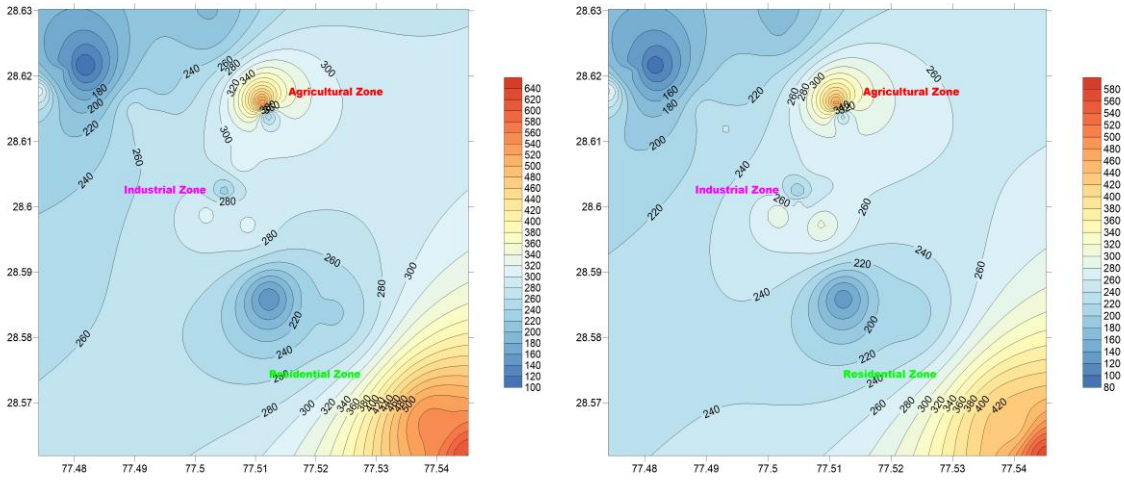
Fig. 5.2.1.54 Box and Whisker plot of Total Alkalinity in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.55 Spatial distribution of Total Alkalinity in Groundwater samples during study period (2016-2018)

5.2.1.12 Chloride

Appreciable amount of chlorides are present in almost all natural water bodies. The range of their concentrations is quite broad and from very dilute to supersaturated solutions of soluble and slightly soluble chloride, especially of sodium chloride. However, in majority of natural surface water bodies, their concentration is usually lesser as compare to other major components. Higher concentration of chloride indicates pollution due to organic wastes of animal origin as well as due to industrial effluents. The source of chloride content in fresh water may be attributed to input from anthropogenic activities.

The level of chloride in water is an essential factor for the selection of supplies for domestic, industrial and agricultural use. Considerable increase in chloride content of water may be connected with the pollution from industrial and household sewage. Human and animal excreta have high quantity of chlorides along with nitrogenous compounds.

The results of the water quality analysis with respect to chloride at all the twenty-two water quality stations of the study area are shown in Table – 5.2.1.23 and 5.2.1.24.

During study period of three years, chloride content of groundwater of study region fluctuated from 9.8 to 442.8 mg/L with a mean value of 135.2 mg/L. Its minimum concentration was recorded from Dujana water quality station in pre-monsoon sample of year 2017. Achheja water quality station in pre-monsoon season of year 2016 gave the maximum value of chloride content. In year 2016, it was found minimum (14.44 mg/L) at Dujana water quality station in post-monsoon season and maximum (442.8 mg/L) at Achheja water quality station in pre-monsoon season with a mean of 147.44 mg/L. During year 2017 & 2018, chloride content of groundwater stretched from 9.80 to 298 mg/L & 15.81 to 340.2 mg/L respectively. In both years, maximum concentration of chloride was obtained from Dujana water quality station. A slight increase in mean value of chloride was observed from 2017 to 2018 (124.10 to 134.10 mg/L).

Table – 5.2.1.23 Seasonal Variation in Chloride concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	76.04	39.20	82.50	2.83%	1.22%	10.46%
			Post-monsoon	73.89	38.72	73.87			
	S2	Duryai	Pre-monsoon	45.60	39.20	45.86	7.57%	-5.48%	8.85%
			Post-monsoon	42.15	41.35	41.80			
	S3	Duryai	Pre-monsoon	32.89	19.60	34.83	6.02%	-65.56%	10.13%
			Post-monsoon	30.91	32.45	31.30			
	S4	Talabpur	Pre-monsoon	25.65	19.60	35.65	2.38%	-10.20%	15.29%
			Post-monsoon	25.04	21.60	30.20			
Industrial	S5	Bisrakh Road	Pre-monsoon	32.60	19.60	28.68	1.20%	-10.15%	11.33%
			Post-monsoon	32.21	21.59	25.43			
	S6	Bisrakh Road	Pre-monsoon	287.80	265.00	330.50	5.56%	2.57%	13.31%
			Post-monsoon	271.80	258.20	286.50			
	S7	Bisrakh Road	Pre-monsoon	163.80	137.20	138.80	2.81%	1.46%	12.61%
			Post-monsoon	159.20	135.20	121.30			
	S8	Bisrakh Road	Pre-monsoon	35.85	29.40	36.21	0.98%	-7.45%	9.42%
			Post-monsoon	35.50	31.59	32.80			
	S9	Bisrakh Road	Pre-monsoon	23.83	19.60	29.12	1.55%	-39.85%	10.95%
			Post-monsoon	23.46	27.41	25.93			
	S10	Khera Dharampura	Pre-monsoon	60.10	58.80	60.18	17.09%	22.99%	13.34%
			Post-monsoon	49.83	45.28	52.15			
	S11	Bishnuli	Pre-monsoon	78.45	49.00	61.69	13.03%	0.35%	8.07%
			Post-monsoon	68.23	48.83	56.71			
	S12	Achheja	Pre-monsoon	442.80	260.00	281.50	5.22%	1.77%	2.56%
			Post-monsoon	419.70	255.40	274.30			
	S13	Achheja	Pre-monsoon	194.80	178.00	193.40	3.08%	8.20%	10.96%
			Post-monsoon	188.80	163.40	172.20			
	S14	Dujana	Pre-monsoon	15.47	9.80	18.15	6.66%	-1.73%	12.89%
			Post-monsoon	14.44	9.97	15.81			
	S15	Dujana	Pre-monsoon	321.50	278.00	265.70	12.69%	12.73%	14.15%
			Post-monsoon	280.70	242.60	228.10			
	S16	Dujana	Pre-monsoon	285.50	298.00	340.20	3.71%	11.68%	13.58%
			Post-monsoon	274.90	263.20	294.00			
	S17	Dujana	Pre-monsoon	252.60	267.00	265.00	3.80%	5.02%	22.42%
			Post-monsoon	243.00	253.60	205.60			
	S18	Badalpur	Pre-monsoon	268.50	294.40	252.10	6.74%	28.43%	13.09%
			Post-monsoon	250.40	210.70	219.10			
Residential	S19	Sadopur	Pre-monsoon	34.89	29.40	29.82	4.16%	11.09%	7.95%
			Post-monsoon	33.44	26.14	27.45			
	S20	Dairy Maccha	Pre-monsoon	180.60	68.60	74.56	33.17%	5.07%	3.58%
			Post-monsoon	120.70	65.12	71.89			
	S21	Dhoom Manikpur	Pre-monsoon	235.00	284.20	289.35	10.81%	14.70%	13.69%
			Post-monsoon	209.60	242.41	249.75			
	S22	Badhpura	Pre-monsoon	315.00	176.40	251.50	26.98%	-5.24%	12.72%
			Post-monsoon	230.00	185.65	219.50			

Table – 5.2.1.24 Statistical Summary of Chloride (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	15.47	Dujana	14.44	Dujana	9.80	Dujana	9.97	Dujana	18.15	Dujana	15.81	Dujana
Max.	442.8	Achheja	419.7	Achheja	298	Dujana	263.2	Dujana	340.2	Dujana	294	Dujana
Mean	154.97		139.90		129.09		119.11		142.97		125.26	
St. Dev.	128.53		117.12		114.36		100.29		117.74		102.22	

In agricultural zone of study area chloride concentration ranged from 19.6 to 82.5 mg/L with a mean value of 40.83 mg/L. In industrial zone a minimum value of 9.8 mg/L (at Dujana water quality station in year 2017) and a maximum value of 442.8 mg/L (at Achheja water quality station in year 2016) of chloride was observed. In residential zone, Sadopur water quality station in year 2017, exhibited a minimum value of chloride (26.14 mg/L) and Badhpura water quality station in year 2016, showed a maximum value of chloride (315 mg/L). Mean value of chloride was found maximum in industrial zone of study area. The decreasing order of mean value of chloride in groundwater samples was 157.35 mg/L (industrial zone) > 152.12 mg/L (residential zone) > 40.83 mg/L (agricultural zone). Discharge of chloride rich industrial effluents and sewage water was responsible for high chloride level in groundwater of industrial and residential area. Similar types of results were reported by Hasalam, 1991; Ackah et al., 2011 and Tambekar et al., 2012.

Percent change of chloride concentration from pre-monsoon to post-monsoon samples showed net dilution of groundwater except at few places- Duryai, Talabpur, Bisrakh Road, Dujana and Badhpura. Out of these Duryai and Bisrakh water quality stations showed significant increase in chloride content of groundwater. Duryai station was in the agricultural zone of study area. Use of potassium fertilizers (KCl, muriate of potash) was very likely seen in this area. Chloride being an anion doesn't adsorb on soil particles and readily moves with water. Hence at this station, percolation of chloride rich water during monsoon season increased the chloride content of groundwater in post-monsoon samples. Several big and small industries were present near the Bisrakh water quality station. Dumping of waste waters from these industries increased the chloride content of groundwater. Kumar et al., (2007) reported the chloride content of groundwater of Patiala and Muktsar, Punjab in both pre and post-monsoon season (130.27 to 171.08 mg/L and 178 to 1270.6 mg/L) respectively. Singh & Singh, (2018) analysed the groundwater quality of Ballia district of Uttar Pradesh and reported that chloride concentration increased in post-monsoon samples from 45.35 to 58.15 mg/L.

The empirical probability distribution plots with respect to chloride at all the twenty-two water quality stations of the study area during study period (2016, 2017 & 2018) are presented in Fig. 5.2.1.56, 5.2.1.57 and 5.2.1.58 respectively. From distribution Plot, it is easy to understand that most of the analysed samples were having chloride content upto 50 mg/L. A very less number of samples exhibited chloride content above 300 mg/L. Box and Whisker plot of chloride in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.1.59. Box and Whisker plot shows that there was a big difference in mean and median value in all three years. Median value was much lower than mean value. It explains that a large number of samples were positioned in lower side of chloride range. Spatial distribution map of chloride was also drawn to understand the distribution pattern of chloride in groundwater of study area (Fig. 5.2.1.60).

BIS has set the acceptable limit of 250 mg/L and permissible limit of 1000 mg/L of chloride in drinking water. Out of total analysed samples, 25.8% of samples were beyond the acceptable limit of BIS for chloride. However all the samples were well below the permissible limit of chloride given by BIS. The samples having chloride value above the acceptable limit were majorly collected from the industrial zone of study area. Dhoom Manikpur and Badhpura water quality station of residential zone also showed elevated level of chloride in groundwater. Rezaei & Hassani, (2018) documented a range of 9 to 1151.4 mg/L of chloride in groundwater of Isfahan, Iran. They also concluded that 18% of samples were above the acceptable limit of BIS for chloride.

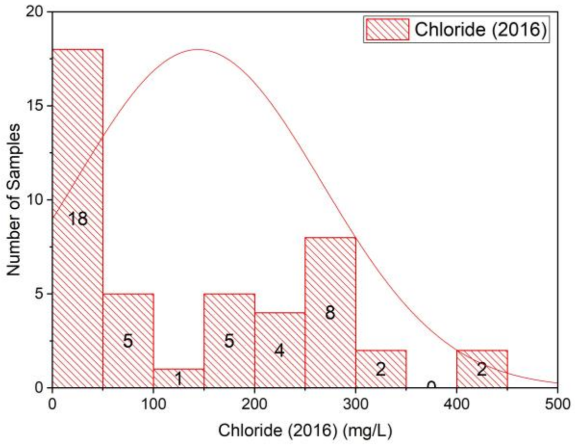


Fig. 5.2.1.56 Empirical probability distribution of Chloride concentration in Groundwater samples (in year 2016)

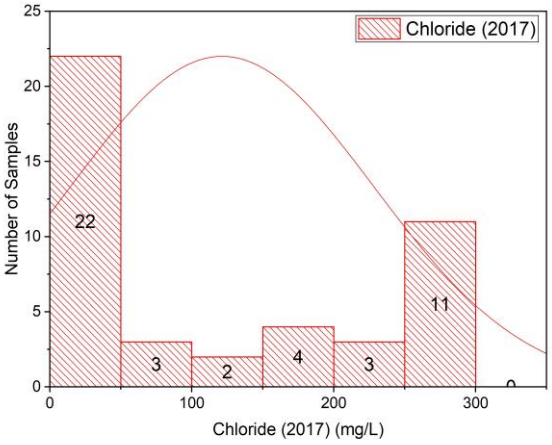


Fig. 5.2.1.57 Empirical probability distribution of Chloride concentration in Groundwater samples (in year 2017)

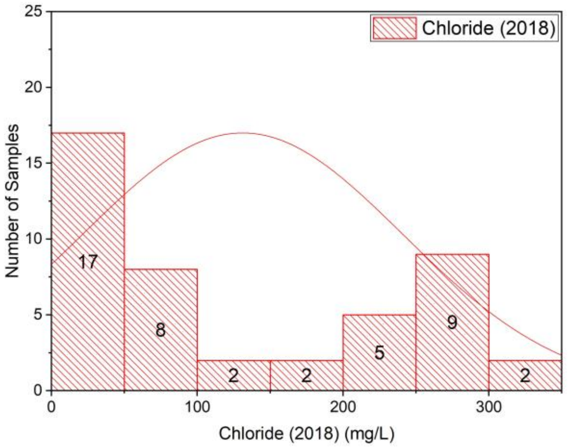


Fig. 5.2.1.58 Empirical probability distribution of Chloride concentration in Groundwater samples

(in year 2018)

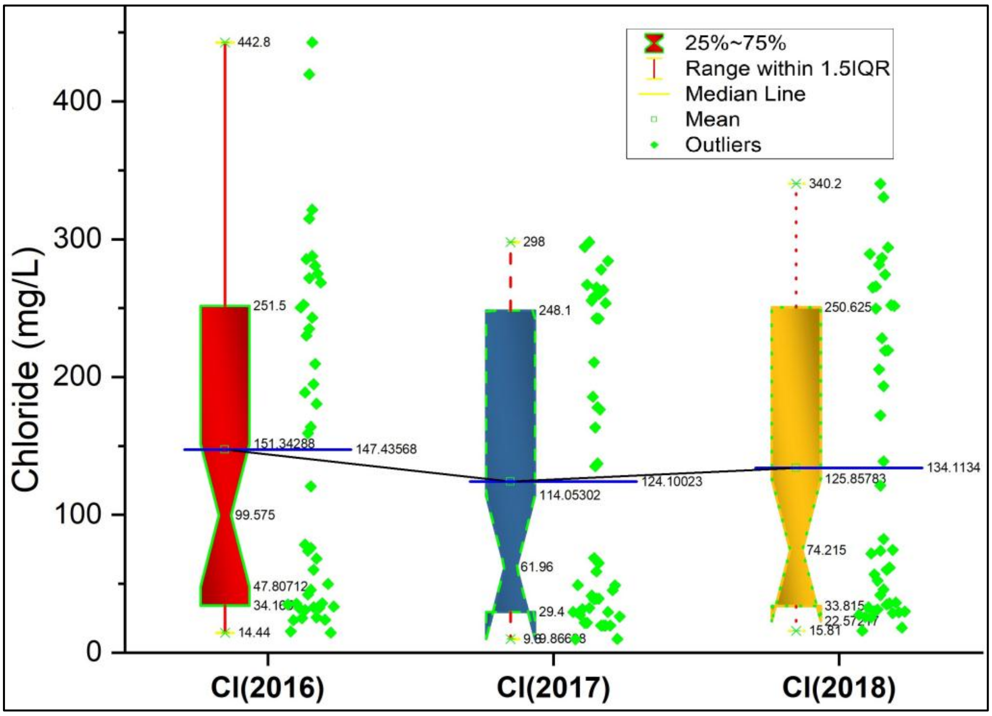
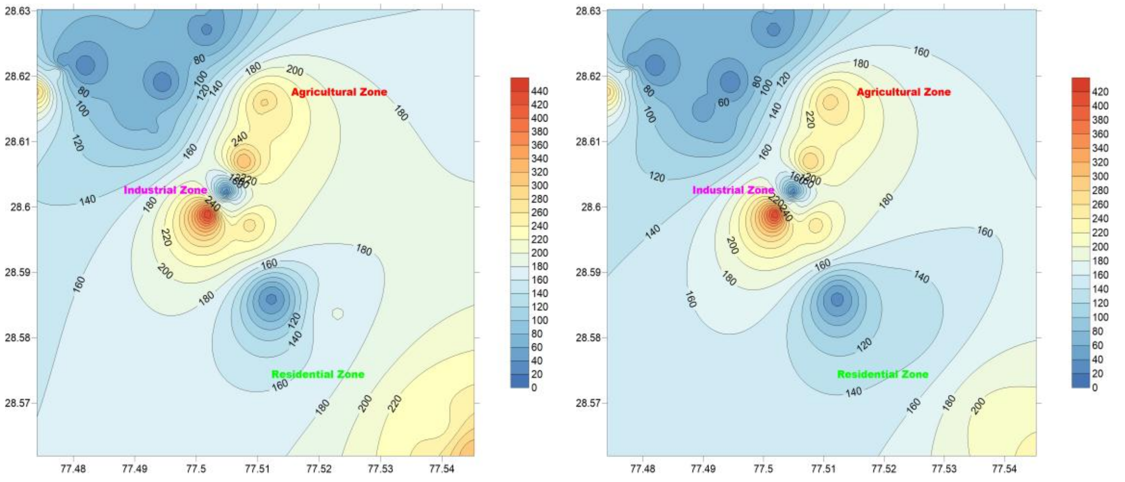
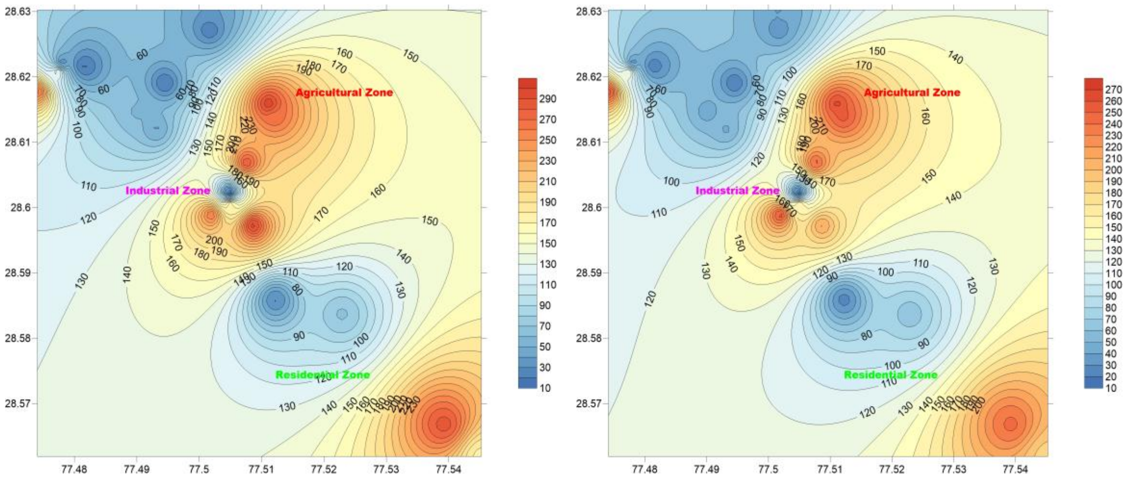


Fig. 5.2.1.59 Box and Whisker plot of Chloride concentration in Groundwater samples during study period (2016-2018)



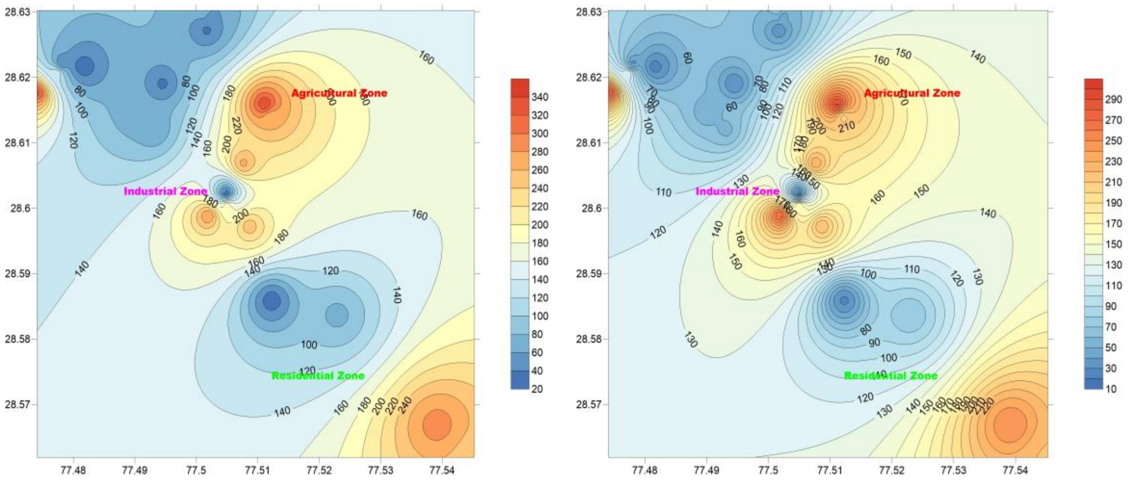
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.60 Spatial distribution of Chloride in Groundwater samples during study period (2016-2018)

5.2.1.13 Fluoride

Fluoride appears in unpolluted natural water in minute quantity due to interchange of ions between water and fluoride containing material. Fluoride content of natural water is controlled by the dissolution of fluoride mineral (fluorapatite fluorspar, cryolite and) containing rocks and the retention time of water among the rocks. Usually fluoride level of natural surface water does not exceed 1 mg/L. The concentration of fluoride is high in surface water mostly due to contribution through agricultural runoffs where phosphatic fertilizers are used and in some occasions through industrial discharges. Fluoride concentration can have beneficial as well as adverse health effects depending upon the amount of dosage. In small amount fluoride prevents dental caries but if its concentration is higher than 1.5 mg/L it causes dental fluorosis. Even in very high concentration (>3 mg/L) it causes skeletal fluorosis, osteosclerosis, thyroid, kidney changes and cardiovascular disorders. World Health Organisation's rules for the maximum amount of fluoride concentration in underground water is 1.5 mg/L. According to Indian standards, the acceptable limit of fluoride concentration is 1.0 mg/L (BIS 2012). This is because of the harsh climate conditions and continuous deficiency of indispensable nutrients like (Vitamin C, E, calcium and antioxidants) in rural areas of India. During the whole study period the analytical results of fluoride in groundwater samples are given in Table – 5.2.1.25 and 5.2.1.26.

The range of fluoride in study area was 0.17 to 2.21 mg/L. The mean value of fluoride during period of study was 0.59 mg/L which is lesser than acceptable limit of fluoride (1 mg/L) in drinking water given by BIS. Its minimum value was analysed in groundwater of Badhpura water quality station in pre-monsoon season of year 2017 while the maximum value was obtained from Achheja water quality station in pre-monsoon sample of year 2016. The maximum value of fluoride (i.e. 2.21 mg/L) was above the permissible limit of fluoride (1.5 mg/L) for potable water (BIS: 10500 2012). The range of fluoride in 2016, 2017, and 2018 was recorded from 0.19 to 2.21 mg/L, 0.17 to 1.31 mg/L and 0.18 to 1.6 mg/L respectively. There was not a significant change in the mean value of fluoride over the consecutive three years of study. The mean value of it in year 2016, 2017 and 2018 was 0.63 ± 0.43, 0.53 ± 0.28 and 0.6 ± 0.351 mg/L respectively. Badhpura water quality station always showed minimum concentration of fluoride in groundwater. In year 2017 and 2018, maximum value was obtained from Achheja station but in year 2018 Dujana station showed the maximum concentration of fluoride.

Table – 5.2.1.25 Seasonal Variation in Fluoride concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	0.50	0.41	0.43	16.10%	5.00%	10.70%
			Post-monsoon	0.42	0.39	0.38			
	S2	Duryai	Pre-monsoon	0.31	0.31	0.33	4.49%	1.92%	14.46%
			Post-monsoon	0.30	0.31	0.28			
	S3	Duryai	Pre-monsoon	0.73	0.53	0.72	22.68%	1.88%	11.73%
			Post-monsoon	0.57	0.52	0.63			
	S4	Talabpur	Pre-monsoon	0.58	0.43	0.68	9.76%	6.03%	18.27%
			Post-monsoon	0.53	0.41	0.56			
Industrial	S5	Bisrakh Road	Pre-monsoon	0.43	0.37	0.35	4.67%	4.81%	15.91%
			Post-monsoon	0.41	0.36	0.30			
	S6	Bisrakh Road	Pre-monsoon	0.43	0.41	0.52	2.57%	1.45%	5.03%
			Post-monsoon	0.42	0.41	0.49			
	S7	Bisrakh Road	Pre-monsoon	0.54	0.47	0.46	7.28%	5.08%	8.53%
			Post-monsoon	0.50	0.45	0.42			
	S8	Bisrakh Road	Pre-monsoon	0.46	0.46	0.44	4.38%	8.35%	13.70%
			Post-monsoon	0.44	0.42	0.38			
	S9	Bisrakh Road	Pre-monsoon	0.52	0.50	0.62	5.95%	4.78%	5.66%
			Post-monsoon	0.49	0.48	0.58			
	S10	Khera Dharampura	Pre-monsoon	0.51	0.44	0.51	9.18%	10.11%	13.02%
			Post-monsoon	0.47	0.39	0.44			
	S11	Bishnuli	Pre-monsoon	0.33	0.46	0.50	8.23%	0.88%	13.97%
			Post-monsoon	0.30	0.45	0.43			
	S12	Achheja	Pre-monsoon	2.21	1.31	1.39	4.52%	2.75%	3.60%
			Post-monsoon	2.11	1.27	1.34			
	S13	Achheja	Pre-monsoon	1.02	0.92	1.12	7.94%	8.79%	11.88%
			Post-monsoon	0.94	0.84	0.99			
	S14	Dujana	Pre-monsoon	1.39	1.09	1.60	7.71%	18.17%	11.12%
			Post-monsoon	1.28	0.89	1.42			
	S15	Dujana	Pre-monsoon	0.46	0.35	0.37	8.48%	8.81%	4.89%
			Post-monsoon	0.42	0.32	0.35			
	S16	Dujana	Pre-monsoon	0.31	0.31	0.35	6.15%	13.69%	10.89%
			Post-monsoon	0.29	0.27	0.31			
	S17	Dujana	Pre-monsoon	0.51	0.50	0.51	3.91%	6.02%	13.70%
			Post-monsoon	0.49	0.47	0.44			
	S18	Badalpur	Pre-monsoon	0.41	0.43	0.49	6.67%	3.52%	9.88%
			Post-monsoon	0.38	0.41	0.44			
Residential	S19	Sadopur	Pre-monsoon	1.03	0.85	0.87	1.36%	8.36%	8.65%
			Post-monsoon	1.01	0.78	0.79			
	S20	Dairy Maccha	Pre-monsoon	0.64	1.00	1.09	7.81%	4.00%	1.83%
			Post-monsoon	0.59	0.96	1.07			
	S21	Dhoom Manikpur	Pre-monsoon	0.89	0.26	0.31	11.24%	4.30%	15.38%
			Post-monsoon	0.79	0.25	0.26			
	S22	Badhpura	Pre-monsoon	0.20	0.17	0.28	5.00%	-22.81%	37.21%
			Post-monsoon	0.19	0.21	0.18			

Table – 5.2.1.26 Statistical Summary of Fluoride (in mg/L) in Groundwater samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.2	Badhpura	0.19	Badhpura	0.17	Badhpura	0.21	Badhpura	0.28	Badhpura	0.18	Badhpura
Max.	2.21	Achheja	2.11	Achheja	1.31	Achheja	1.27	Achheja	1.60	Dujana	1.42	Dujana
Mean	0.65		0.61		0.54		0.51		0.63		0.57	
St. Dev.	0.45		0.42		0.29		0.27		0.36		0.3445	

After analyzing the results on the basis of different zone, it is found that groundwater of agricultural zone was fit for drinking (0.28 to 0.73 mg/L). In residential zone, few samples of Sadopur (in year 2016) and Dairy Maccha (in year 2018) have fluoride content higher than the acceptable limit of 1.0 mg/L while rest of the analysed samples were suitable for drinking. In industrial zone, the value of fluoride varied from 0.27 to 2.21 mg/L with a mean value of 0.61 mg/L. Groundwater of achheja and Dujana quality stations have fluoride content higher than the 1.0 mg/L. At these places in year 2016 & 2018, fluoride content of groundwater was much greater than the permissible limit of BIS. The results of analysis indicate that groundwater of industrial zone of study area was partially fit for drinking. Nasir et al., (2017) investigated the quality of underground water in Faisalabad industrial area and recorded a range of ND to 2 mg/L of fluoride. They also documented that fluoride concentration is increasing over the period and affecting human health.

Percent change in fluoride value from pre-monsoon to post-monsoon samples always indicates dilution of groundwater due to rainfall. Only one sample collected from Badhpura water quality station in year 2017 showed fluoride enrichment in post-monsoon sample. The reason behind this unusual result was percolation of fluoride rich leachate. Similar type of results were also obtained in Ghaziabad region (Mean concentration of fluoride in groundwater- 0.82 mg/L in pre-monsoon season & 0.70 mg/L in post-monsoon season) by Singh et al., 2014.

Distribution plot of fluoride content in groundwater samples during the study period (2016, 2017 & 2018) at all twenty-two water quality stations is presented in Fig. 5.2.1.61, 5.2.1.62 & 5.2.1.63 respectively. Most of the samples lie in range of 0.4 to

0.6 mg/L of fluoride. Box and Whisker plot was also drawn to know the distributional characterstics of fluoride values of groundwater during study period. A wide variation between mean value and mean value is observed. Spatial distribution map of fluoride content of groundwater in study area reveals that in year 2016, fluoride contamination was limited to industrial area only but in consecutive years, fluoride contamination spreaded to residential zone (Fig. 5.2.1.65).

On comparing the results of fluoride analysis with the drinking standards of BIS, nearly 10.6% of samples have fluoride content higher than the acceptable limit but below the permissible limit. These samples can be used for drinking in absence of alternative source of drinking water. Only three samples of industrial zone showed fluoride concentration above the permissible limit and not fit for drinking. Manjeet et al., (2014) reported a range of 0.02 to 6.4 mg/L of fluoride in groundwater of Gurgaon city and analysed that 24% of samples were having fluoride content above 1.5 mg/L. Several researchers documented the fluoride concentration in groundwater and its health effects on humans (Dar et al., 2011; Ravikumar et al., 2011; Li et al., 2014; Sunitha et al., 2014).

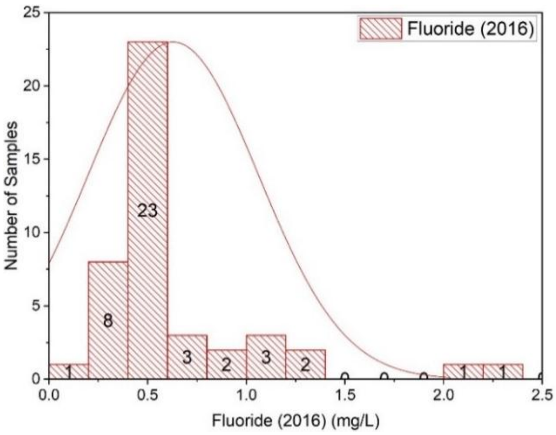


Fig. 5.2.1.61 Empirical probability distribution of Fluoride concentration in Groundwater samples (in year 2016)

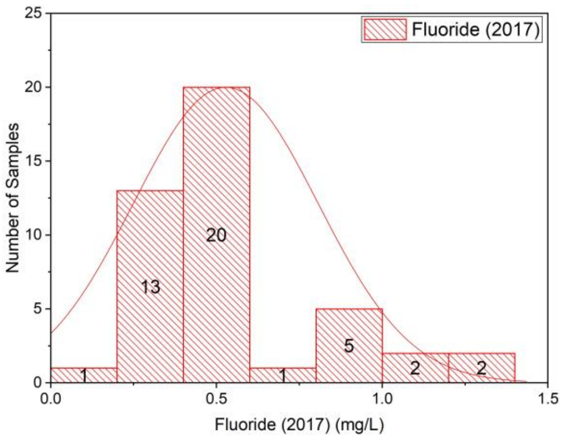


Fig. 5.2.1.62 Empirical probability distribution of Fluoride concentration in Groundwater samples (in year 2017)

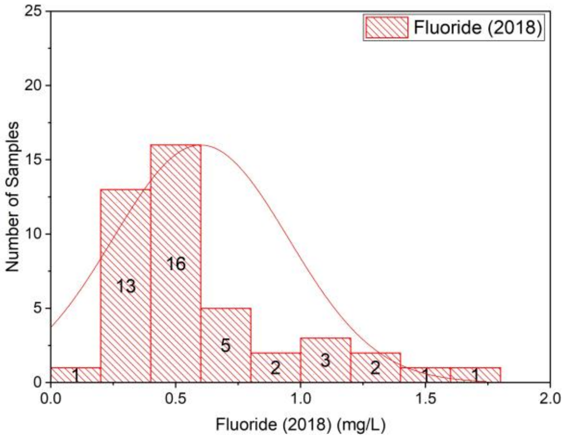


Fig. 5.2.1.63 Empirical probability distribution of Fluoride concentration in Groundwater samples (in year 2018)

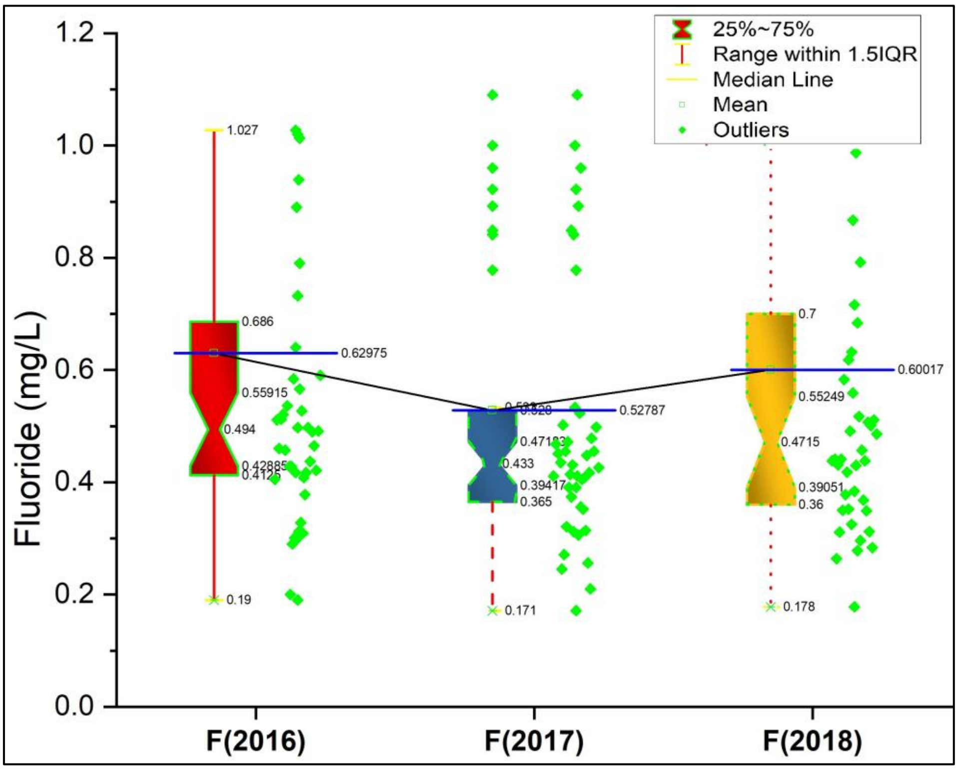
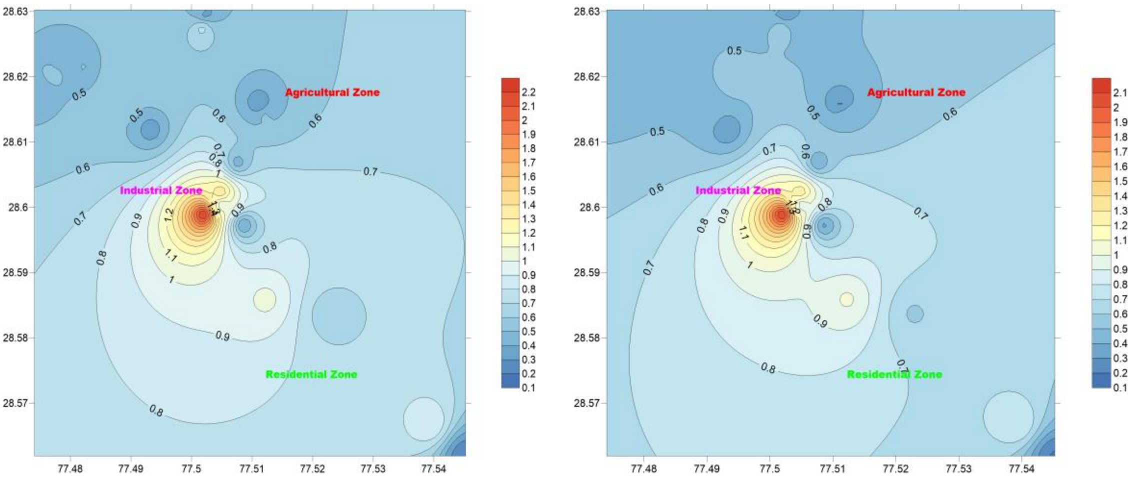
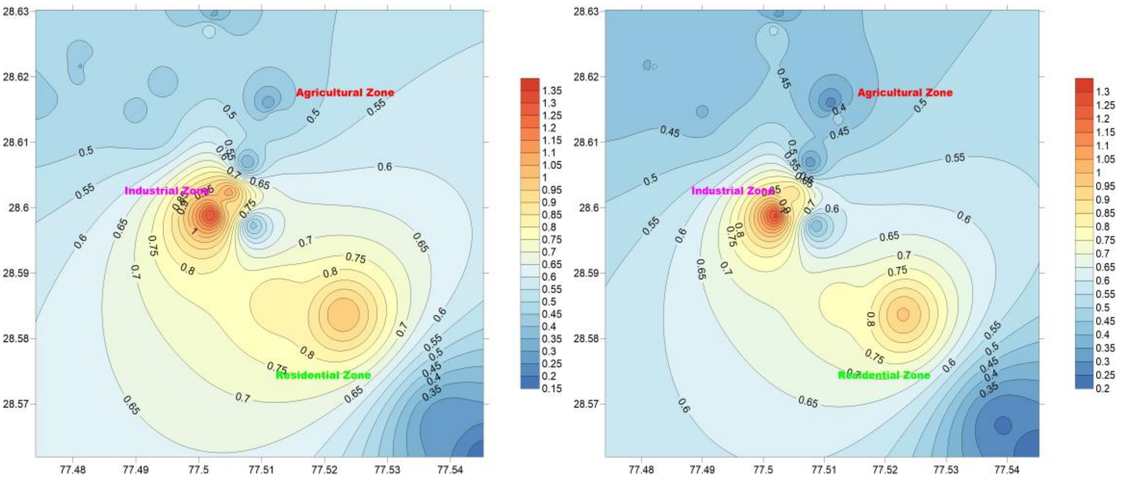


Fig. 5.2.1.64 Box and Whisker plot of Fluoride concentration in Groundwater samples during study period (2016-2018)



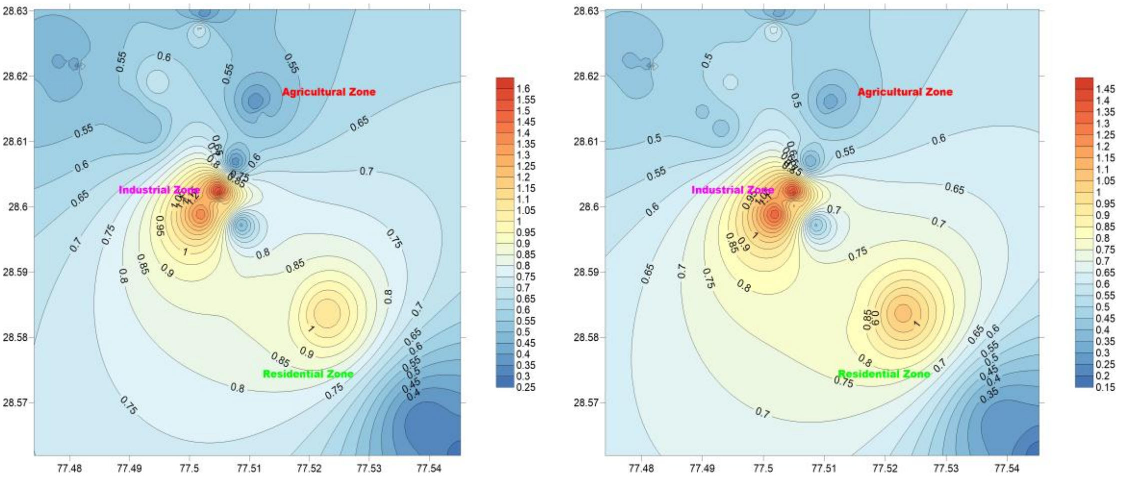
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.65 Spatial distribution of Fluoride in Groundwater samples during study period (2016-2018)

5.2.1.14 Nitrite

There are no mineral source of nitrite ion in the natural water. Nitrite represents an intermediate during nitrification and denitrification reaction in the nitrogen cycle. Nitrite is a very unstable ion and appears in the water chiefly as a result of biochemical oxidation of ammonia or the reduction of nitrate. In surface water with sufficient oxygen and high value of oxidizing reducing potential, process of bio-chemcial oxidation is predominate. Presence of even a small quantity of nitrite may indicate the pollution (including fecal) of the water body and the availability of partially oxidized nitrogenous matter as cited by Upadhyay, 1998. Nitrite may also be produced in distribution system through the activities of mirco-organism on ammonia added during treatment of water (chloramination).

Results of nitrite analysis in three consecutive years are given in Table – 5.2.1.27 and 5.2.1.28. During the study period, the range of nitrite content in groundwater of study area was 0.09 to 0.35 mg/L with a mean of 0.239 mg/L. Small concentration of nitrite ion was obtained in groundwater as it readily oxidized into stable nitrate ion. During 2016 the variation in nitrite in groundwater was from 0.1 to 0.33 mg/L with a mean value of 0.24 ± .07 while, in 2017 it ranged from a minimum of 0.09 mg/L to a maximum of 0.35 mg/L. It is observed that values ranged from 0.14 to 0.34 mg/L during 2018. In year 2016 it was found maximum at Bisrakh water quality station. In year 2017 the minimum nitrite concentration was observed at Dujana water quality station and maximum at Bisrakh with a mean of 0.23 ± .07 mg/L. In 2018 it was found maximum at Bisrakh site and minimum at Khera Dharampura water quality station with a mean of 0.25 ± 0.053 mg/L.

In agricultural zone, nitrite concentration extended from 0.14 to 0.31mg/L with a mean value of 0.23 mg/L. The groundwater nitrite content in industrial zone ranged between 0.09 and 0.35 mg/L providing a mean value of 0.23 mg/L. Residential zone of study area also has a wide range of nitrite concentration with a minimum value of 0.24 mg/L and a maximum value of 0.33 mg/L with a mean of 0.29 mg/L. In residential zone Sadopur water quality station has maximum nitrite in groundwater. The mean value of nitrite was maximum in residential zone of study area.

Percent change of nitrite concentration of groundwater showed a decrease in post-monsoon samples as compared to pre-monsoon samples.

Table – 5.2.1.27 Seasonal Variation in Nitrite concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

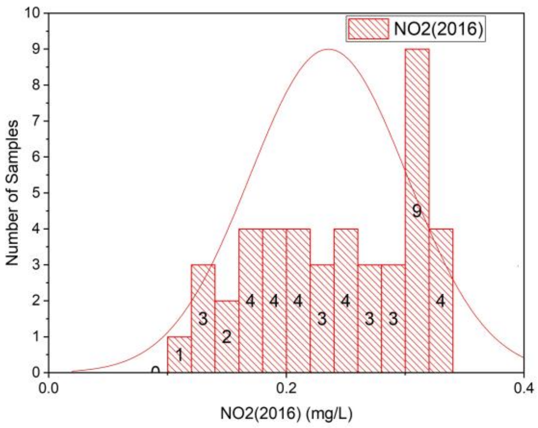
Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	0.21	0.22	0.24	9.52%	4.55%	12.50%
			Post-monsoon	0.19	0.21	0.21			
	S2	Duryai	Pre-monsoon	0.31	0.26	0.27	3.23%	3.85%	7.41%
			Post-monsoon	0.3	0.25	0.25			
	S3	Duryai	Pre-monsoon	0.27	0.27	0.23	3.70%	18.52%	8.70%
			Post-monsoon	0.26	0.22	0.21			
	S4	Talabpur	Pre-monsoon	0.17	0.16	0.28	11.76%	12.50%	7.14%
			Post-monsoon	0.15	0.14	0.26			
Industrial	S5	Bisrakh Road	Pre-monsoon	0.31	0.35	0.34	9.68%	11.43%	8.82%
			Post-monsoon	0.28	0.31	0.31			
	S6	Bisrakh Road	Pre-monsoon	0.21	0.2	0.21	9.52%	20.00%	14.29%
			Post-monsoon	0.19	0.16	0.18			
	S7	Bisrakh Road	Pre-monsoon	0.31	0.29	0.3	6.45%	10.34%	16.67%
			Post-monsoon	0.29	0.26	0.25			
	S8	Bisrakh Road	Pre-monsoon	0.33	0.3	0.33	15.15%	3.33%	12.12%
			Post-monsoon	0.28	0.29	0.29			
	S9	Bisrakh Road	Pre-monsoon	0.18	0.19	0.23	5.56%	15.79%	8.70%
			Post-monsoon	0.17	0.16	0.21			
	S10	Khera Dharampura	Pre-monsoon	0.13	0.12	0.15	0.00%	8.33%	6.67%
			Post-monsoon	0.13	0.11	0.14			
	S11	Bishnuli	Pre-monsoon	0.26	0.25	0.26	3.85%	4.00%	3.85%
			Post-monsoon	0.25	0.24	0.25			
	S12	Achheja	Pre-monsoon	0.18	0.17	0.21	11.11%	0.00%	9.52%
			Post-monsoon	0.16	0.17	0.19			
	S13	Achheja	Pre-monsoon	0.22	0.26	0.31	4.55%	11.54%	6.45%
			Post-monsoon	0.21	0.23	0.29			
	S14	Dujana	Pre-monsoon	0.12	0.12	0.17	16.67%	25.00%	11.76%
			Post-monsoon	0.1	0.09	0.15			
	S15	Dujana	Pre-monsoon	0.16	0.18	0.21	12.50%	0.00%	4.76%
			Post-monsoon	0.14	0.18	0.2			
	S16	Dujana	Pre-monsoon	0.23	0.18	0.2	8.70%	5.56%	5.00%
			Post-monsoon	0.21	0.17	0.19			
	S17	Dujana	Pre-monsoon	0.24	0.27	0.27	4.17%	7.41%	3.70%
			Post-monsoon	0.23	0.25	0.26			
	S18	Badalpur	Pre-monsoon	0.31	0.3	0.32	3.23%	6.67%	3.13%
			Post-monsoon	0.3	0.28	0.31			
Residential	S19	Sadopur	Pre-monsoon	0.32	0.33	0.28	6.25%	6.06%	3.57%
			Post-monsoon	0.3	0.31	0.27			
	S20	Dairy Maccha	Pre-monsoon	0.31	0.3	0.3	0.00%	3.33%	6.67%
			Post-monsoon	0.31	0.29	0.28			
	S21	Dhoom Manikpur	Pre-monsoon	0.32	0.33	0.31	0.00%	15.15%	3.23%
			Post-monsoon	0.32	0.28	0.3			
	S22	Badhpura	Pre-monsoon	0.25	0.27	0.3	4.00%	11.11%	3.33%
			Post-monsoon	0.24	0.24	0.29			

Table – 5.2.1.28 Statistical Summary of Nitrite (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.12	Dujana	0.1	Dujana	0.12	Khera Dharampura	0.09	Dujana	0.15	Khera Dharampura	0.14	Khera Dharampura
Max.	0.33	Bisrakh Road	0.32	Dhoom Manikpur	0.35	Bisrakh Road	0.31	Sadopur	0.34	Bisrakh Road	0.31	Badalpur
Mean	0.24		0.23		0.24		0.22		0.26		0.24	
St. Dev.	0.07		0.07		0.07		0.06		0.053		0.051	

The empirical probability distribution plots with respect to nitrite at all the twenty-two water quality stations of the study area during study period (2016, 2017 & 2018) are shown in Fig. 5.2.1.66, 5.2.1.67 and 5.2.1.68 respectively. Box and Whisker plot is also drawn to know the distributional characterstics of nitrite values of groundwater during study period (Fig. 5.2.1.69). Spatial distribution map of nitrite content in groundwater of study area, further demonstrate scenario of nitrite contamination (Fig. 5.2.1.70).

BIS does not recommend any standard value for nitrite in potable water however WHO gave a guideline value of 3 mg/L as nitrite ion (WHO, 2017). Guidelines for Canadian drinking water quality also gave a value of 3 mg/L as nitrite ion in drinking water (Health Canada, 2013). Major sources of nitrite to humans are vegetables and preservatives in cured meat. A considerable amount of nitrite can enters in body of bottle-fed infants through water. This is most sensitive group of population against methaemoglobinaemia disease. Results of nitrite analysis concluded that all of analysed samples have nitrite concentration well below the guideline value of WHO for nitrite. Farshad & Imandel, (2003) reported a range of 0.29 to 314.22 mg/L of nitrite in industrial sites of Tehran. Magesh et al., (2013) documented nitrite content in groundwater of Dindigul district of Tamilnadu- 0.05 to 87 mg/L. Nezhad et al., (2017) analysed groundwater of Shiraz city of south-central Iran and reported the nitrite range of 0 to 0.025 mg/L.



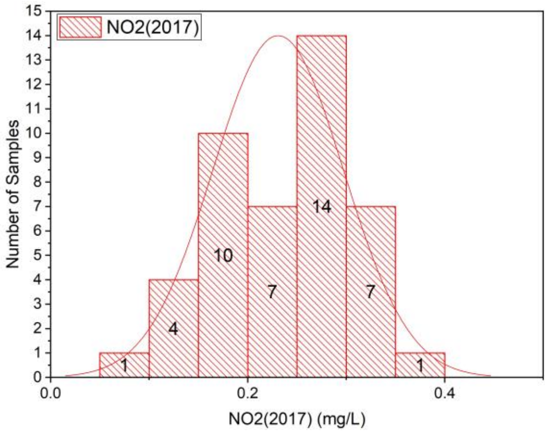


Fig. 5.2.1.66 Empirical probability distribution of Nitrite concentration in Groundwater samples (in year 2016)

Fig. 5.2.1.67 Empirical probability distribution of Nitrite concentration in Groundwater samples (in year 2017)

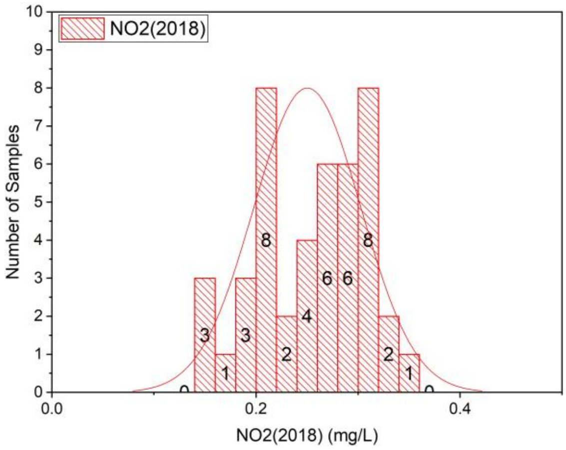


Fig. 5.2.1.68 Empirical probability distribution of Nitrite concentration in Groundwater samples (in year 2018)

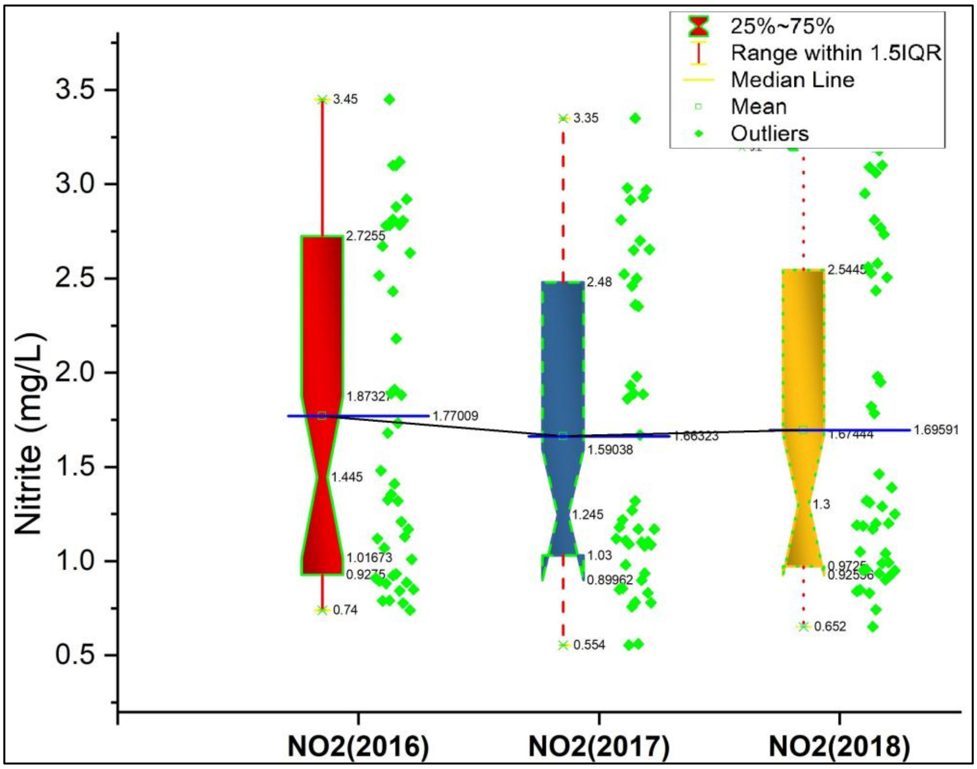
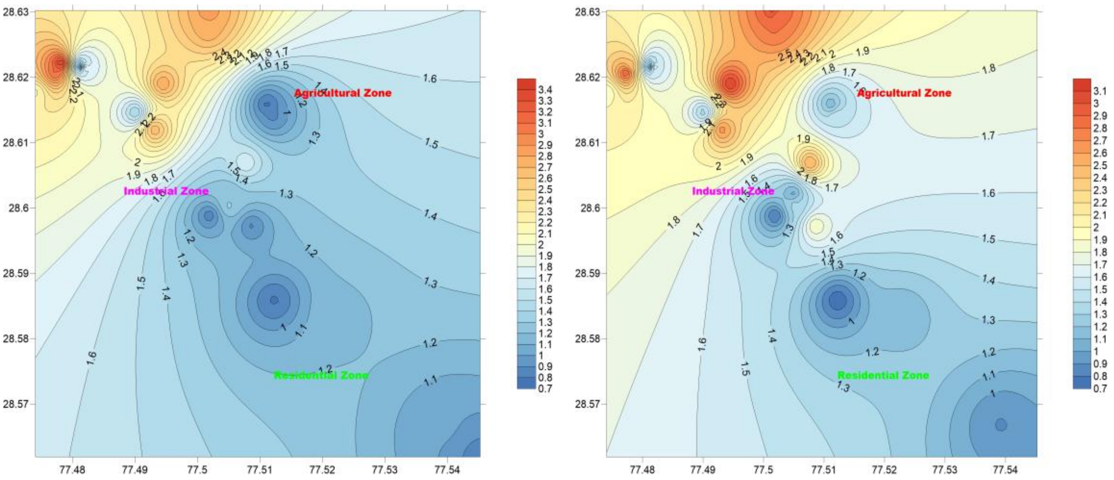
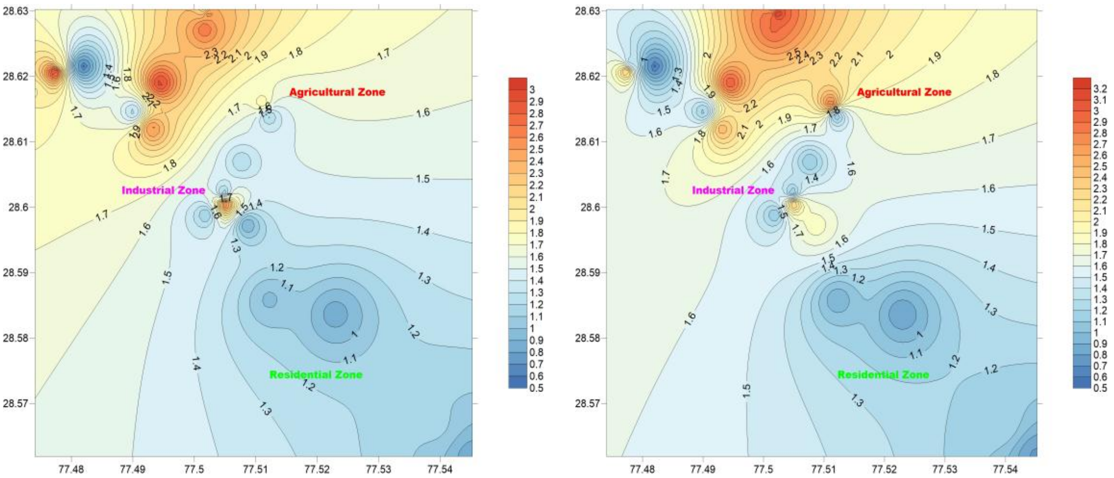


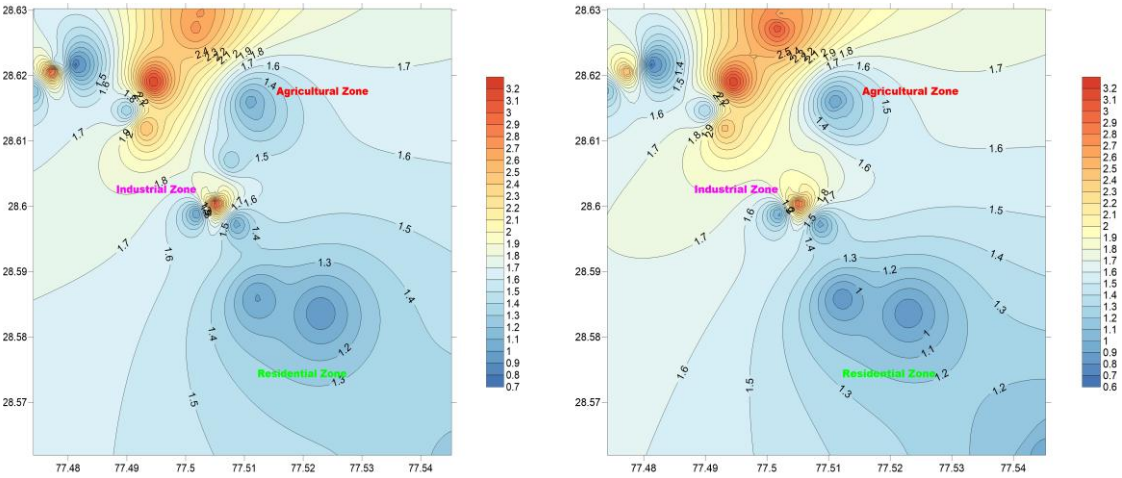
Fig. 5.2.1.69 Box and Whisker plot of Nitrite concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.70 Spatial distribution of Nitrite in Groundwater samples during study period (2016-2018)

5.2.1.15 Nitrate

Nitrate is naturally found in water bodies in small quanity but due to various human activities its concentration has increased. Different point sources like untreated domestic sewage, waste disposal, accumulation of liquid manure at a place and non point sources like agricultural runoff, geological deposition, precipitation of atmospheric nitrogen, nitrogen fixation, decomposition of dead/decaying animals & plants are the various sources of nitrate contamination in groundwater (Harper et al., 1983). It is considered as second most pollutant of groundwater which threats environment (Spalding & Exner, 1993). Recently several researchers documented the elevated level of groundwater nitrate due to agricultural activities.

The analytical results of nitrate in groundwater samples are given in Table – 5.2.1.29 and 5.2.1.30.

The range of nitrate in groundwater during study period was 38.4 to 496 mg/L with a mean of 206.3 mg/L. According to Indian standards for drinking water, the maximum concentration of nitrate should be 45 mg/L in drinking water. The obtained mean value in current study, was much higher than the desirable limit of BIS. Its base value was recorded from Dhoom Manikpur water quality station in pre-monsoon season of 2016. The upper limit of nitrate was obtained from Bisrakh water quality station in pre-monsoon sample of Year 2018. In year 2016 it was recorded maximum at Bisrakh water quality station (445 mg/L) and minimum at Dhoom Manikpur water quality station with a mean value of 207.52 ± 88.99 mg/L. In year 2017 a decrease in mean value of nitrate was observed compared to year 2016. During 2018 mean nitrate value increased from 194.96 (in year 2017) to 216.4 (in year 2018) mg/L. During whole study period (from 2016 to 2018) always Bisrakh water quality station showed maximum concentration of nitrate in groundwater.

Table – 5.2.1.29 Seasonal Variation in Nitrate concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	349.60	308.00	341.20	8.30%	4.68%	13.31%
			Post-monsoon	320.60	293.60	295.80			
	S2	Duryai	Pre-monsoon	207.00	210.00	217.56	7.00%	4.38%	12.81%
			Post-monsoon	192.50	200.80	189.70			
	S3	Duryai	Pre-monsoon	197.00	201.00	198.30	9.29%	9.15%	12.51%
			Post-monsoon	178.70	182.60	173.50			
	S4	Talabpur	Pre-monsoon	237.60	216.00	323.10	1.94%	3.61%	8.45%
			Post-monsoon	233.00	208.20	295.80			
Industrial	S5	Bisrakh Road	Pre-monsoon	205.80	208.00	206.70	-1.26%	1.63%	13.45%
			Post-monsoon	208.40	204.60	178.90			
	S6	Bisrakh Road	Pre-monsoon	190.60	173.00	200.80	-2.76%	-3.58%	1.74%
			Post-monsoon	195.87	179.20	197.30			
	S7	Bisrakh Road	Pre-monsoon	441.00	433.00	496.00	-0.91%	-1.15%	16.53%
			Post-monsoon	445.00	438.00	414.00			
	S8	Bisrakh Road	Pre-monsoon	250.40	260.00	239.80	2.24%	14.69%	11.34%
			Post-monsoon	244.80	221.80	212.60			
	S9	Bisrakh Road	Pre-monsoon	251.30	244.00	246.50	-1.59%	5.86%	9.33%
			Post-monsoon	255.30	229.70	223.50			
	S10	Khera Dharampura	Pre-monsoon	302.10	276.00	360.20	10.33%	-0.94%	13.88%
			Post-monsoon	270.90	278.60	310.20			
	S11	Bishnuli	Pre-monsoon	255.70	253.00	252.60	3.75%	4.15%	12.59%
			Post-monsoon	246.10	242.50	220.80			
	S12	Achheja	Pre-monsoon	304.80	180.00	189.50	-0.66%	-0.78%	-0.63%
			Post-monsoon	306.80	181.40	190.70			
	S13	Achheja	Pre-monsoon	230.50	205.00	258.90	-0.91%	-1.76%	10.62%
			Post-monsoon	232.60	208.60	231.40			
	S14	Dujana	Pre-monsoon	139.80	108.00	175.10	9.73%	9.93%	-1.54%
			Post-monsoon	126.20	97.28	177.80			
	S15	Dujana	Pre-monsoon	148.10	107.00	155.30	-4.25%	-4.49%	-2.45%
			Post-monsoon	154.40	111.80	159.10			
	S16	Dujana	Pre-monsoon	100.40	101.00	140.50	-2.39%	-4.75%	8.61%
			Post-monsoon	102.80	105.80	128.40			
	S17	Dujana	Pre-monsoon	91.17	71.00	82.18	-4.67%	2.59%	-5.65%
			Post-monsoon	95.43	69.16	86.82			
	S18	Badalpur	Pre-monsoon	208.50	210.00	267.60	-2.06%	-2.24%	3.29%
			Post-monsoon	212.80	214.70	258.80			
Residential	S19	Sadopur	Pre-monsoon	121.40	102.00	108.30	-1.15%	5.38%	-1.27%
			Post-monsoon	122.80	96.51	109.67			
	S20	Dairy Maccha	Pre-monsoon	204.63	318.00	348.90	-1.60%	1.32%	12.58%
			Post-monsoon	207.90	313.80	305.00			
	S21	Dhoom Manikpur	Pre-monsoon	38.40	41.00	47.23	-10.16%	-18.61%	-6.39%
			Post-monsoon	42.30	48.63	50.25			
	S22	Badhpura	Pre-monsoon	140.00	108.00	132.00	14.29%	-9.26%	8.18%
			Post-monsoon	120.00	118.00	121.20			

Table-5.2.1.30 Statistical Summary of Nitrate (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	38.4	Dhoom Manikpur	42.3	Dhoom Manikpur	41	Dhoom Manikpur	48.63	Dhoom Manikpur	47.23	Dhoom Manikpur	50.25	Dhoom Manikpur
Max.	441	Bisrakh Road	445	Bisrakh Road	433	Bisrakh Road	438	Bisrakh Road	496	Bisrakh Road	414	Bisrakh Road
Mean	209.81		205.24		196.95		192.97		226.74		205.97	
St. Dev.	91.19		88.83		93.19		90.70		103.8		84.619	

In agricultural zone of study area nitrate concentration varied from 173.5 to 349.6 mg/L with a mean value 240.47 mg/L. Industrial zone of study area has wide range of nitrate with a minimum value of 69.16 mg/L and maximum value of 496 mg/L. Residential zone also showed high nitrate value in groundwater (38.4 to 348.9 mg/L). In industrial zone Dujana water quality station showed a minimum nitrate concentration while Bisrakh water quality station showed a maximum nitrate concentration. The increasing order of mean nitrate value in three different zone was-140.25 mg/L (residential zone) < 215.38 mg/L (industrial zone) < 240.47 mg/L (agricultural zone).

On the basis of percent change in nitrate value from pre-monsoon to post-monsoon season, it is observed that in agricutural areas always dilution of ground aquifers occured after monsoon. But at few water quality stations in industrial and residential zone, nitrate concentration of groundwater increased after rainfall. The study area was densely populated and due to lack of proper sanitary conditions a large quantity of human and animal excreta mixed with soil layers. Percolation of nitrogenous matter with rain water caused increase in nitrate content of groundwater. A rise in nitrate content of groundwater was also reported by Singh et al., (2013) in Bathinda district of Punjab. They concluded that 33% of analysed samples in pre-monsoon season (NO_3 level up to 83 mg/L) and 45% samples in post-monsoon season (NO_3 level upto 90 mg/L) were not suitable for drinking.

The empirical probability distribution plot and box-whisker plot of nitrate content in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.1.71, 5.2.1.72, 5.2.1.73 and 5.2.1.74 respectively. Graphical figures reveal that data is symmetrically distributed during study period however majority of samples were in range of 150 to 250 mg/L of nitrate. Spatial distribution map of nitrate content of groundwater in study area also showed relative level of nitrate at studied water quality stations (Fig. 5.2.1.75). Groundwater nitrate pollution problem is more prevalent in rural areas than urban areas because of livestock farming (Singh & Sekhon, 1976).

Methemoglobinemia is the common disease associated with excess of nitrate in drinking water. Nitrate itself is relatively non-toxic. But in human body, it gets converted to nitrites which react with heamoglobin in the blood and oxidize Fe^{+2} to Fe^{+3} and forms methemoglobin. This methemoglobin cannot bind oxygen, hence decreases the capacity of the blood to transport oxygen. When less oxygen is transported from the lungs to the body tissues, it causes a condition known as methemoglobinemia. Adults can tolerate little higher nitrate concentrations. On the basis of standard value of nitrate of BIS, nearly 97.7% of analysed samples were beyond the limit. Leaching of agricultural waste water and nitrification of nitrogen present in human and animal excreta were responsible for high nitrate content of groundwater in study region. Ahada & Suthar, (2018) analysed nitrate content of groundwater of Malwa, Punjab and reported nitrate range; 38.45 to 198.05 mg/L in eastern Malwa and 46.43 to 163.30 mg/L in western Malwa. Gaikwad et al., (2019) reported nitrate content (0.5 to 14.8 mg/L) of underground water in western coastal part of Maharashtra. Similar type of studies were done by many workers (Elisante & Muzuka 2017; Daw et al., 2018; Ducci, 2018; Zhang et al. 2018).

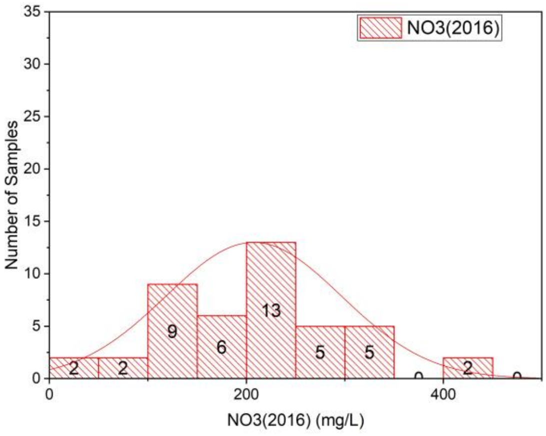


Fig. 5.2.1.71 Empirical probability distribution of Nitrate concentration in Groundwater samples (in year 2016)

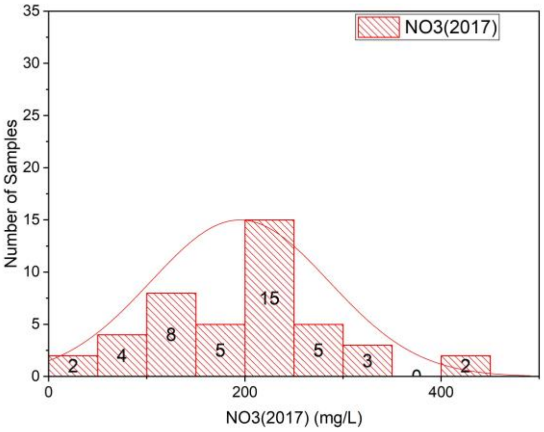


Fig. 5.2.1.72 Empirical probability distribution of Nitrate concentration in Groundwater samples (in year 2017)

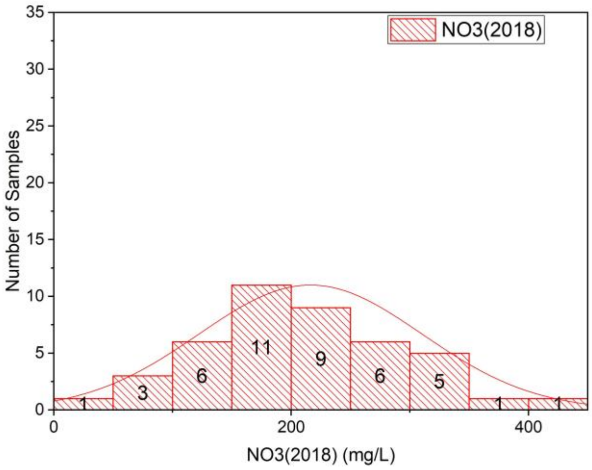


Fig. 5.2.1.73 Empirical probability distribution of Nitrate concentration in Groundwater samples (in year 2018)

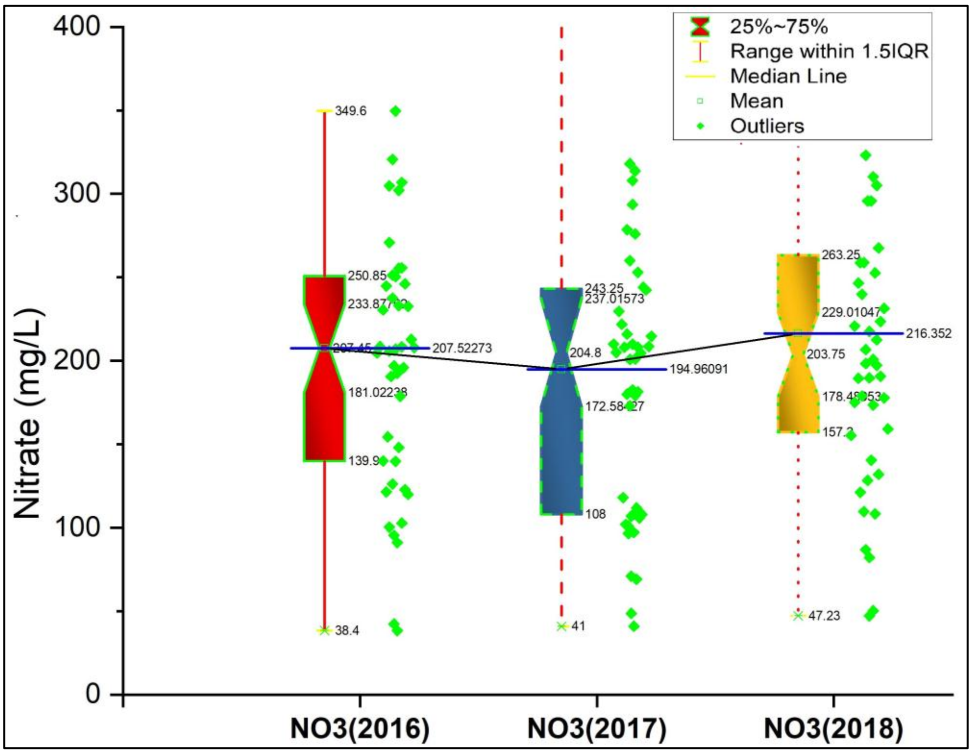
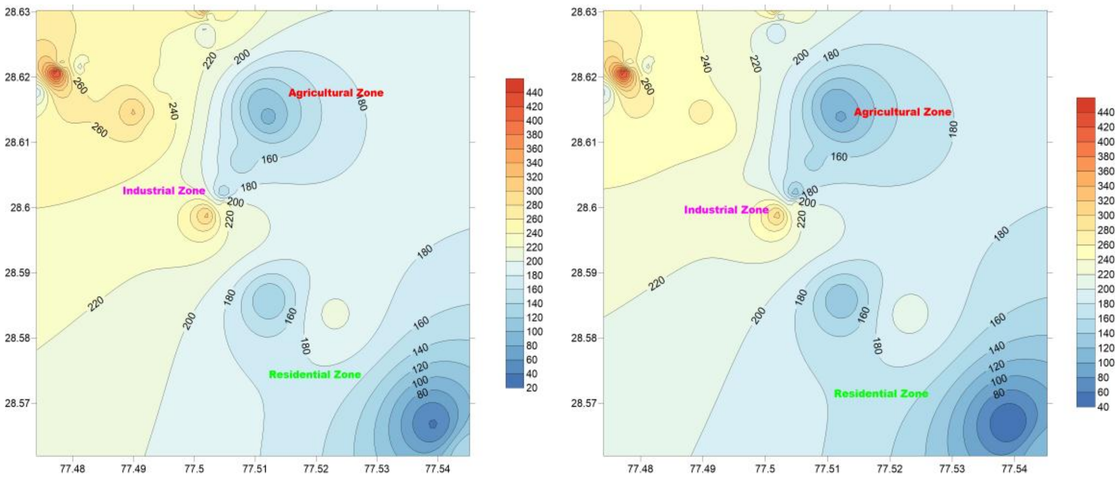
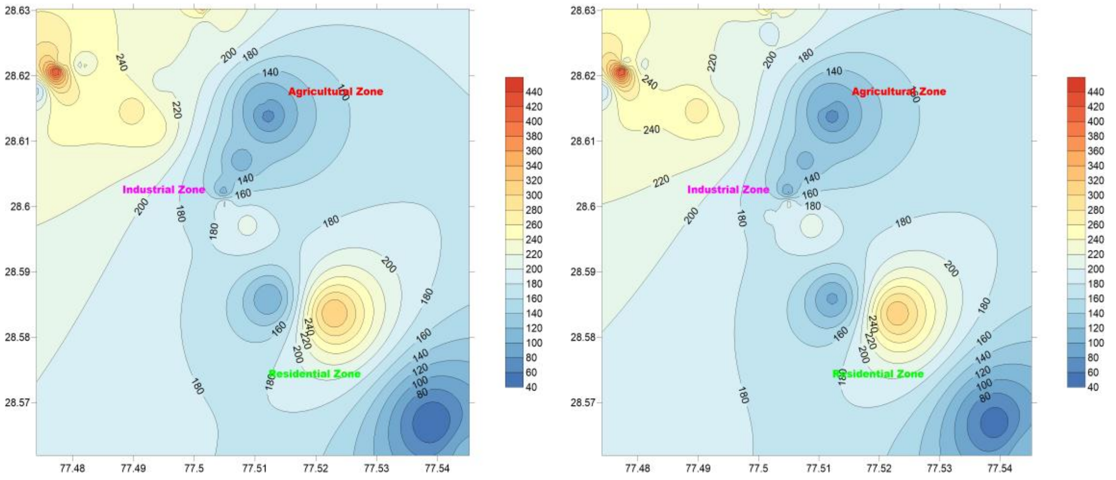


Fig. 5.2.1.74 Box and Whisker plot of Nitrate concentration in Groundwater samples during study period (2016-2018)



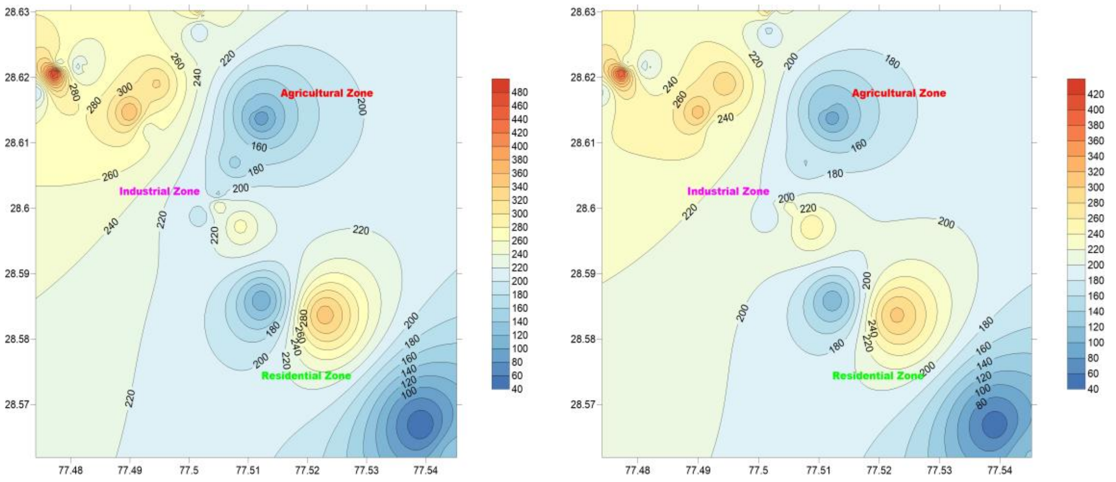
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.75 Spatial distribution of Nitrate in Groundwater samples during study period (2016-2018)

5.2.1.16 Phosphate

Phosphorous occurs in natural waters almost solely as phosphates rather than in free state. Phosphorous occurs both in inorganic and organic forms (as bound in the organismal matter). Only inorganic phosphorous (as orthophosphates) plays a dynamic role in an aquatic ecosystem. Phosphorous is a component of sewage, as it is essential in metabolism and always present in animal metabolic waste. The natural source of phosphate is the phosphorous bearing rocks. The high phosphate concentration is related to waste disposal. Phosphates are contributed to natural waters through dissolutions from soil, discharged sewage and industrial effluents, particularly from fertilizer factories. Phosphate is pointed out as an indicator of aquatic pollution by organic matter and it is the principal causative agent for the eutrophication of water bodies and consequential degradation.

Phosphorus data have great importance in envrionmental studies because of their significance as a vital factor in life process. In unpolluted water bodies, phosphates are formed mainly during certain biological process of transformation of organic substances to inorganic phosphate. During the vegetation period, the phosphates in soluble form are readily taken up by aquatic plants, mainly phytoplankton. Considerable irregular increase in the concentration of phosphate indicates the presence of pollutants. Major sources of this are domestic sewage, detergent, agricultural run-off with fertilizer and industrial waste waters (Fadiran et al., 2008).

During the whole study period the analytical results of phosphate in groundwater samples are given in Table – 5.2.1.31 and 5.2.1.32.

The range of phosphate in study region was 0.14 to 3.85 mg/L with mean value 1.11 mg/L. Badhpura station has minimum concentration of phosphate in year 2016 while Talabpur water quality station has maximum concentration of phosphate in groundwater. Talabpur station was in agricultural zone of study area and use of phosphate fertilizers enhanced the phosphorus content of groundwater. During study period, phosphate content ranged from 0.14 to 3.17 mg/L in year 2016; 0.39 to 2.87 mg/L in year 2017 and 0.48 to 3.85 mg/L in year 2018. Percolation of phosphorus rich water increases the phosphate level in groundwater (Rajankar et al., 2011).

Table – 5.2.1.31 Seasonal Variation in Phosphate concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	1.89	1.21	1.68	13.28%	5.79%	18.93%
			Post-monsoon	1.64	1.14	1.36			
	S2	Duryai	Pre-monsoon	1.06	1.89	2.05	7.36%	4.44%	17.95%
			Post-monsoon	0.98	1.81	1.68			
	S3	Duryai	Pre-monsoon	1.03	0.91	1.06	13.30%	20.55%	13.21%
			Post-monsoon	0.89	0.72	0.92			
	S4	Talabpur	Pre-monsoon	0.64	2.41	3.85	17.57%	9.54%	0.13%
			Post-monsoon	0.53	2.18	3.84			
Industrial	S5	Bisrakh Road	Pre-monsoon	0.55	0.73	0.72	1.28%	3.28%	14.46%
			Post-monsoon	0.54	0.71	0.62			
	S6	Bisrakh Road	Pre-monsoon	1.18	2.87	1.87	9.32%	12.20%	10.16%
			Post-monsoon	1.07	2.52	1.68			
	S7	Bisrakh Road	Pre-monsoon	3.17	1.81	0.98	34.38%	44.20%	20.63%
			Post-monsoon	2.08	1.01	0.78			
	S8	Bisrakh Road	Pre-monsoon	0.44	1.65	0.81	3.66%	55.27%	11.90%
			Post-monsoon	0.42	0.74	0.71			
	S9	Bisrakh Road	Pre-monsoon	0.87	0.41	0.56	4.25%	5.35%	14.80%
			Post-monsoon	0.83	0.39	0.48			
	S10	Khera Dharampura	Pre-monsoon	0.72	1.01	0.94	9.60%	17.92%	11.50%
			Post-monsoon	0.65	0.83	0.83			
	S11	Bishnuli	Pre-monsoon	1.03	0.97	0.73	5.63%	4.25%	14.34%
			Post-monsoon	0.97	0.92	0.63			
	S12	Achheja	Pre-monsoon	0.67	0.81	0.86	19.97%	3.20%	3.15%
			Post-monsoon	0.54	0.79	0.83			
	S13	Achheja	Pre-monsoon	0.97	1.23	1.29	1.96%	11.38%	-24.81%
			Post-monsoon	0.95	1.09	1.61			
	S14	Dujana	Pre-monsoon	0.44	0.68	1.12	9.28%	9.37%	12.41%
			Post-monsoon	0.40	0.62	0.98			
	S15	Dujana	Pre-monsoon	1.06	0.91	1.17	9.34%	11.09%	5.98%
			Post-monsoon	0.96	0.81	1.10			
	S16	Dujana	Pre-monsoon	1.02	1.21	1.34	3.82%	8.43%	8.21%
			Post-monsoon	0.98	1.11	1.23			
	S17	Dujana	Pre-monsoon	1.00	1.25	1.32	2.51%	5.60%	15.15%
			Post-monsoon	0.97	1.18	1.12			
	S18	Badalpur	Pre-monsoon	1.00	0.90	1.03	8.04%	3.89%	20.59%
			Post-monsoon	0.92	0.87	0.81			
Residential	S19	Sadopur	Pre-monsoon	0.87	1.78	1.48	2.41%	23.03%	10.34%
			Post-monsoon	0.85	1.37	1.33			
	S20	Dairy Maccha	Pre-monsoon	1.09	1.12	1.13	9.27%	0.89%	13.81%
			Post-monsoon	0.99	1.11	0.97			
	S21	Dhoom Manikpur	Pre-monsoon	0.87	0.98	0.89	-59.77%	-3.06%	-15.73%
			Post-monsoon	1.39	1.01	1.03			
	S22	Badhpura	Pre-monsoon	0.52	0.79	1.12	73.08%	-24.05%	24.11%
			Post-monsoon	0.14	0.98	0.87			

Table – 5.2.1.32 Statistical Summary of Phosphate (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	0.43	Bisrakh Road	0.14	Badhpura	0.41	Bisrakh Road	0.39	Bisrakh Road	0.56	Bisrakh Road	0.48	Bisrakh Road
Max.	3.17	Bisrakh Road	2.08	Bisrakh Road	2.87	Bisrakh Road	2.52	Bisrakh Road	3.84	Dujana	3.84	Talabpur
Mean	1		0.90		1.25		1.09		1.27		1.15	
St. Dev.	0.58		0.42		0.59		0.50		0.68		0.6897	

Phosphate concentration in agricultural zone ranged from 0.53 to 3.85 mg/L, in industrial zone 0.39 to 3.17 mg/L and in residential zone 0.14 to 1.78 mg/L. Maximum mean phosphate value was obtained from the agricutural zone of study area. The decreasing order for mean value of phosphate was; agricultural zone (1.56 mg/L) > residential zone (1.03 mg/L) > industrial zone (1.01 mg/L). After analyzing the results of phosphate analysis, it is observed that industrial effluent and agricultural activities were two vital factors for elevated concentration of phosphate in groundwater.

During study period, distribution plots of phosphate content of groundwater samples are presented in Fig. 5.2.1.76, 5.2.1.77 & 5.2.1.78. Plot shows that most of the samples were in range of 0.5 to 1.5 mg/L of phosphate. Box and whisker plot reflects a wide variation in phosphate values of groundwater samples (Fig. 5.2.1.79). Many outliers were present in quantile plot. These outliers were of samples collected from Duryai and Bisrakh road stations. Spatial distribution map of phosphate content of groundwater samples represents level of phosphate contamination in groundwater at studied water quality stations (Fig. 5.2.1.80).

Both natural and human factors govern the phosphate content of groundwater. Naturally phosphorus can enters into water bodies through atmospheric deposition, dissolution of phosphate mineral containing rocks, decomposition of organic matter, surface runoff, and sedimentation. Human activities like use of fertilizers, septic tank effluent, animal excreta, domestic waste water (containing detergents), industrial waste water, mining process, water treatment, and synthetic material processing also adds significant quantity of phosphate to water bodies (Mueller et al., 1995; Spruill et al., 1998). The composition of the infiltrating rain water depends on the frequency of rainfall, soil environment and agricultural pattern of the area. In study area, dilution of groundwater was observed after monsoon season. Due to alluvial soil groundwater recharge process was prevailing in the study area. In few samples of Dhoom Manikpur and Badhpura, a rise in phosphate concentration was recorded after monsoon season. Khanikar et al., (2017) recorded a range of 0 to 0.96 mg/L in groundwater samples of Dhekiajuli of Assam.

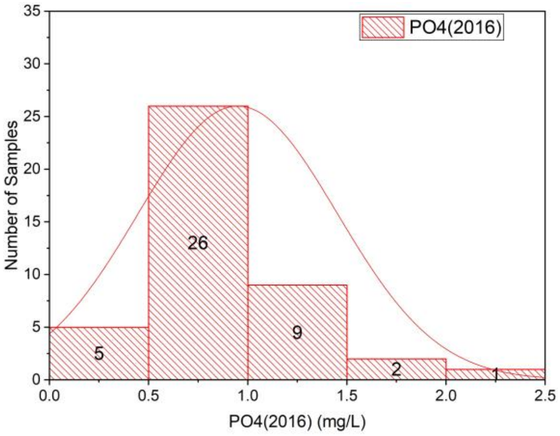


Fig. 5.2.1.76 Empirical probability distribution of Phosphate concentration in Groundwater samples (in year 2016)

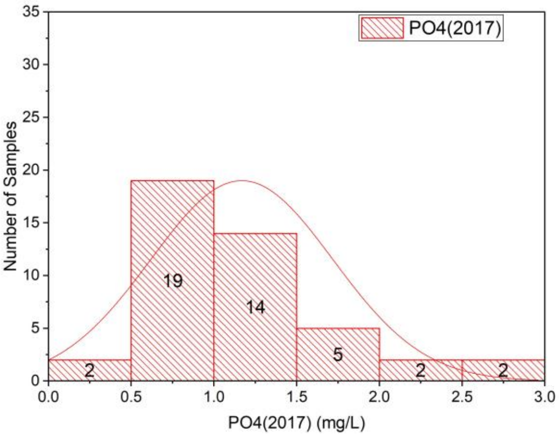


Fig. 5.2.1.77 Empirical probability distribution of Phosphate concentration in Groundwater samples (in year 2017)

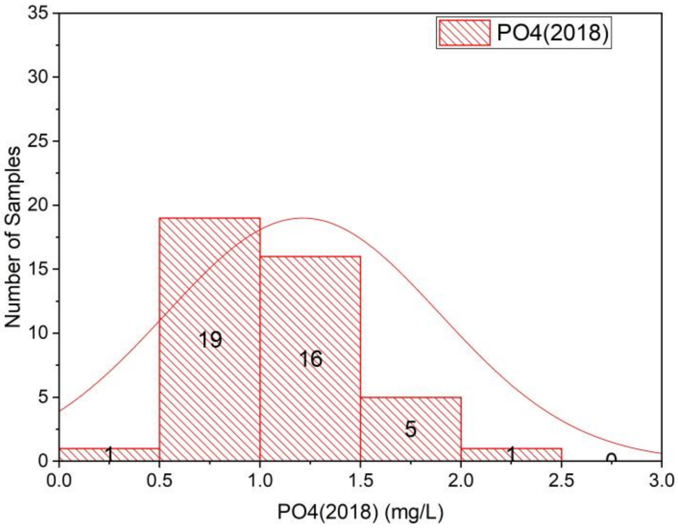


Fig. 5.2.1.78 Empirical probability distribution of Phosphate concentration in Groundwater samples (in year 2018)

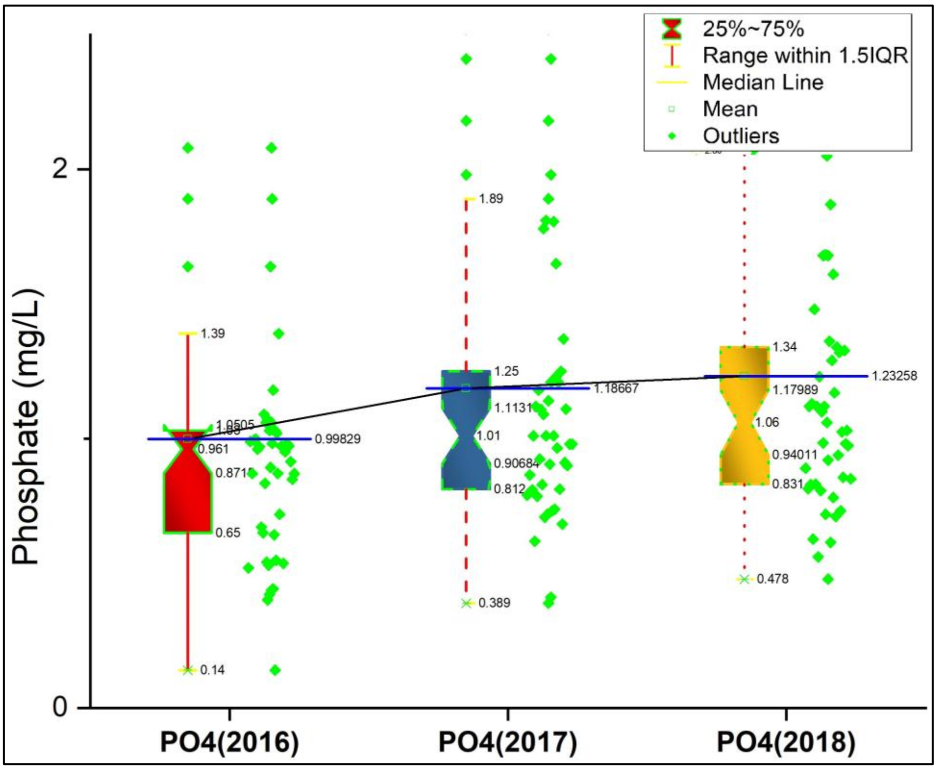
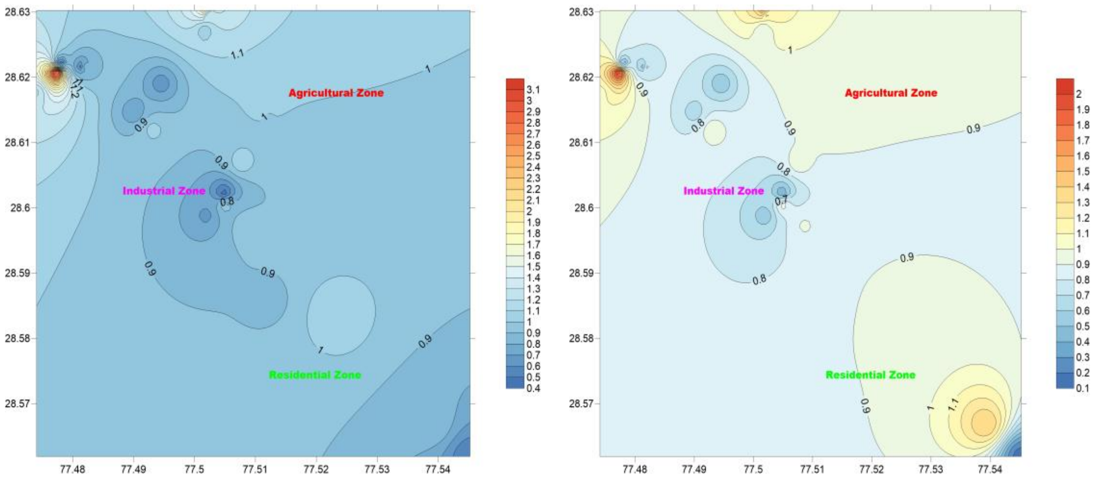
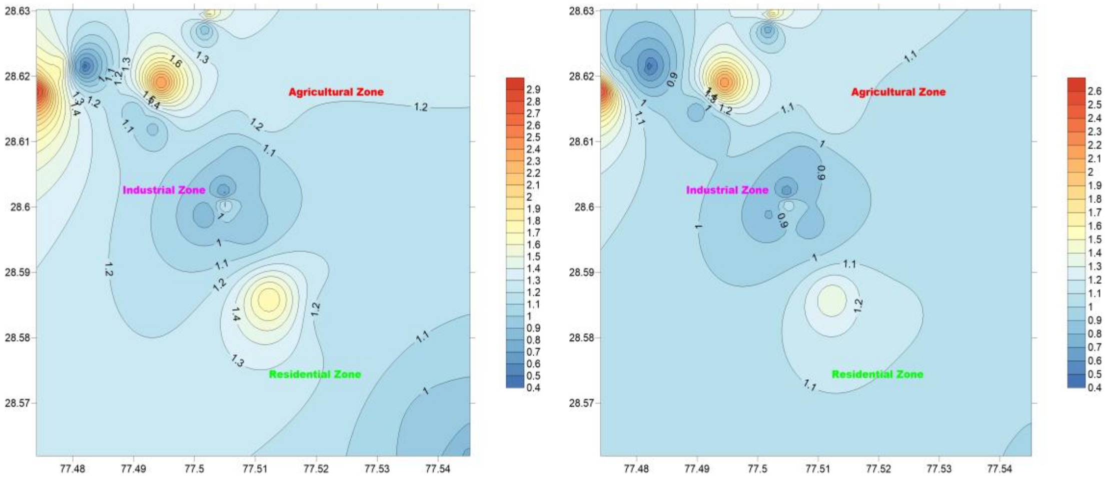


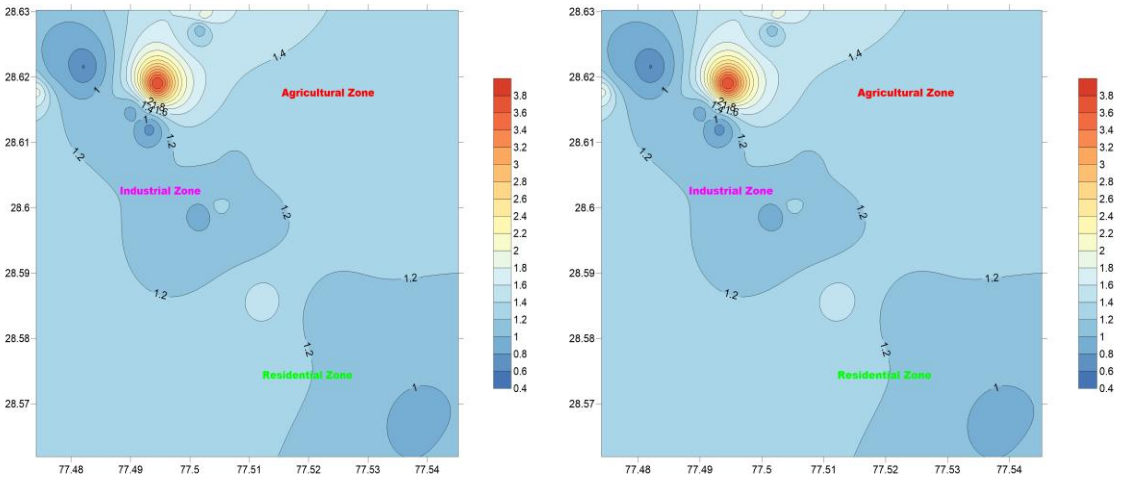
Fig. 5.2.1.79 Box and Whisker plot of Phosphate concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.80 Spatial distribution of Phosphate in Groundwater samples during study period (2016-2018)

5.2.1.17 Sulphate

The sulphate anion is present in natural water ranging from traces to very high concentration. Sulphates of calcium and magnesium impart permanent hardness to the water. Under natural conditions, sulphate content of aquifers depends upon weathering of sulphur containing rocks and biochemical oxidation of sulphur compounds. Suitability of water for domestic and industrial purpose is also decided from the sulphate content of it. Excessive concentration of sulphate in drinking water causes cathartic effect upon humans. It is utilized by all organisms in inorganic as well as organic forms. Sulphate concentration of water for sanitary and hygienic use is not strictly defined (250 mg/L US and Canada). At higher concentration it causes gastrointestinal irritation in the presence of magnesium or sodium. Increase in sulphate concentration may be attributed to the pollution of water bodies. High concentration of sulphate in surface water may be due to oxidation of metal sulphates which is discharged by various industries. The majority of sulphates are soluble in water with the exceptions of sulphates of lead, barium and strontium.

Analytical results of sulphate in all twenty-two groundwater samples are given in Table – 5.2.1.33 and 5.2.1.34.

The sulphate content in underground water of study area varied from 1.38 to 451.5 mg/L with a mean value of 96.66 mg/L. The base limit of sulphate was obtained from post-monsoon sample of 2018 from Duryai water quality station. The upper limit of sulphate was recorded from pre-monsoon sample of 2016 from Achheja water quality station. During 2016, variation in sulphate content of groundwater was from 1.67 to 451.5 mg/L with a mean value of 103.45 mg/L while, in 2017 it ranged from a minimum of 1.65 mg/L to a maximum of 298 mg/L. It was observed that values ranged from 1.38 to 319.8 mg/L during 2018. In year 2016 it was found maximum at Achheja water quality station and in year 2017 the minimum sulphate concentration was observed at Duryai water quality station and maximum at Dujana with a mean of 89.41 ± 106.62 mg/L. In 2018 it was found maximum at Dujana site and minimum at Duryai water quality station with a mean of 97.12 ± 115 mg/L. A fluctuating pattern of sulphate values in groundwater of study area reflects anthropogenic source of it.

Table – 5.2.1.33 Seasonal Variation in Sulphate concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	98.40	85.00	94.46	10.03%	2.65%	11.94%
			Post-monsoon	88.53	82.75	83.18			
	S2	Duryai	Pre-monsoon	8.32	4.44	4.84	14.28%	7.43%	15.07%
			Post-monsoon	7.13	4.11	4.11			
	S3	Duryai	Pre-monsoon	1.87	1.91	1.93	10.53%	13.56%	28.67%
			Post-monsoon	1.67	1.65	1.38			
	S4	Talabpur	Pre-monsoon	15.16	14.69	23.57	6.60%	-0.75%	10.27%
			Post-monsoon	14.16	14.80	21.15			
Industrial	S5	Bisrakh Road	Pre-monsoon	3.85	3.91	2.86	15.06%	26.01%	16.87%
			Post-monsoon	3.27	2.89	2.38			
	S6	Bisrakh Road	Pre-monsoon	160.90	143.00	152.80	5.03%	1.05%	1.90%
			Post-monsoon	152.80	141.50	149.90			
	S7	Bisrakh Road	Pre-monsoon	61.80	57.20	39.80	5.66%	20.28%	6.18%
			Post-monsoon	58.30	45.60	37.34			
	S8	Bisrakh Road	Pre-monsoon	8.68	9.40	8.92	0.86%	23.97%	11.89%
			Post-monsoon	8.60	7.15	7.86			
	S9	Bisrakh Road	Pre-monsoon	4.04	4.25	5.43	0.74%	26.68%	11.17%
			Post-monsoon	4.01	3.12	4.83			
	S10	Khera Dharampura	Pre-monsoon	2.93	2.69	3.11	11.00%	11.00%	15.00%
			Post-monsoon	2.61	2.39	2.65			
	S11	Bishnuli	Pre-monsoon	4.64	5.20	4.71	7.07%	1.92%	13.41%
			Post-monsoon	4.31	5.10	4.08			
	S12	Achheja	Pre-monsoon	451.50	267.00	290.80	3.46%	1.46%	1.34%
			Post-monsoon	435.90	263.10	286.90			
	S13	Achheja	Pre-monsoon	209.70	189.00	204.90	2.05%	9.15%	11.37%
			Post-monsoon	205.40	171.70	181.60			
	S14	Dujana	Pre-monsoon	34.20	26.00	41.49	8.45%	7.08%	13.71%
			Post-monsoon	31.31	24.16	35.80			
	S15	Dujana	Pre-monsoon	311.50	255.00	281.70	9.53%	9.49%	12.53%
			Post-monsoon	281.80	230.80	246.40			
	S16	Dujana	Pre-monsoon	276.10	279.00	319.80	2.90%	11.54%	13.35%
			Post-monsoon	268.10	246.80	277.10			
	S17	Dujana	Pre-monsoon	305.00	298.00	313.80	2.13%	4.43%	12.36%
			Post-monsoon	298.50	284.80	275.00			
	S18	Badalpur	Pre-monsoon	261.10	267.00	309.80	4.86%	3.11%	13.23%
			Post-monsoon	248.40	258.70	268.80			
Residential	S19	Sadopur	Pre-monsoon	38.60	33.00	34.41	6.48%	1.64%	9.15%
			Post-monsoon	36.10	32.46	31.26			
	S20	Dairy Maccha	Pre-monsoon	25.64	43.00	46.90	10.73%	3.95%	16.27%
			Post-monsoon	22.89	41.30	39.27			
	S21	Dhoom Manikpur	Pre-monsoon	17.87	11.84	10.96	11.08%	22.04%	-2.28%
			Post-monsoon	15.89	9.23	11.21			
	S22	Badhpura	Pre-monsoon	36.50	23.69	52.50	35.10%	-50.27%	1.90%
			Post-monsoon	23.69	35.60	51.50			

Table – 5.2.1.34 Statistical Summary of Sulphate (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	1.87	Duryai	1.67	Duryai	1.91	Duryai	1.65	Duryai	1.93	Duryai	1.38	Duryai
Max.	451.5	Achheja	435.9	Achheja	298	Dujana	284.8	Dujana	319.8	Dujana	286.9	Achheja
Mean	106.29		100.61		92.01		86.81		102.25		91.986	
St. Dev.	134.26		129.14		111.14		104.46		122.51		109.64	

On the basis of land use pattern in current study area, sulphate concentration in groundwater has significant variations. In agricultural zone sulphate concentration ranged from 1.38 to 98.4 mg/L with a mean value of 28.30 mg/L. Sulphate analysis of groundwater of industrial zone gave a minimum value of 2.38 mg/L and a maximum value of 451.5 mg/L with a mean of 135.17 mg/L. The sulphate concentration in residential zone ranged between 9.23 and 52.5 mg/L providing a mean value of 30.22 mg/L. The high mean value of sulphate in groundwater of industrial area may be related to dumping of industrial effluent without proper treatment. Many researchers (Ullah et al., 2009; Devi & Kumar, 2012; Nasir et al., 2017; Selvakumar et al., 2017) found that industrial discharge added a significant amount of sulphate in groundwater.

During pre-monsoon season, a rise in sulphate concentration was observed due to evaporation process and lowering of groundwater level. The sulphate concentration reduced in post-monsoon season due to rainfall recharge. However at Badhpura water quality station sulphate content increased after monsoon period in year 2017 due to local pollution (domestic wastes and dissolution of precipitated salts).

The empirical probability distribution plots of sulphate in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.1.81, 5.2.1.82 and 5.2.1.83 respectively. Most of groundwater samples have sulphate content below 100 mg/L. Box and Whisker plot was also drawn to know the distributional characterstics of sulphate values of groundwater during study period. From the plot it is clear that median value is much lower tha mean value and closer to minimum obtained value of sulphate in groundwater. Spatial distribution of sulphate in groundwater samples of study area is given in Fig. 5.2.1.85.

The BIS has set the sulphate content of 200 mg/L for safe drinking water as desirable limit while its permissible limit is prescribed as 400 mg/L in the absence of any other alternative sources. Nearly 75% of analysed samples were within the desirable limit of sulphate given by BIS. Two samples collected from Achheja water quality station in year 2016 were beyond the permissible limit of BIS. Sulphate from drinking water is poorly absorbed in the human intestine and slowly penetrates into the cellular membranes of mammals and is rapidly eliminated through the kidneys. Sodium sulphate and magnesium sulphate exert a cathartic action in human beings. It is also associated with respiratory diseases. Corrosion of water distribution pipes can happen due to sulphate present in water. A range of 11 to 837 mg/L of sulphate was reported by Singh et al., (2011) in parts of Noida metropolitan city. A range of 2 to 1,300 mg/L of sulphate in Greater Noida sub-basin was given by Singh & Hussian, (2016). Li et al., (2016) reported a range of 3.39 to 2772 mg/L of sulphate in groundwater of Tengger desert in northwest China. They divided the study area into two parts- the alluvial plain in the south and the desert region in the north. The sulphate concentration was found higher in alluvial plain than desert region due to evaporation of shallow ground aquifers in alluvial plain.

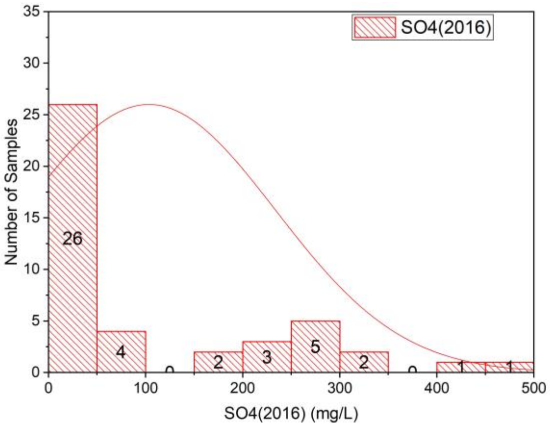


Fig. 5.2.1.81 Empirical probability distribution of Sulphate concentration in Groundwater samples (in year 2016)

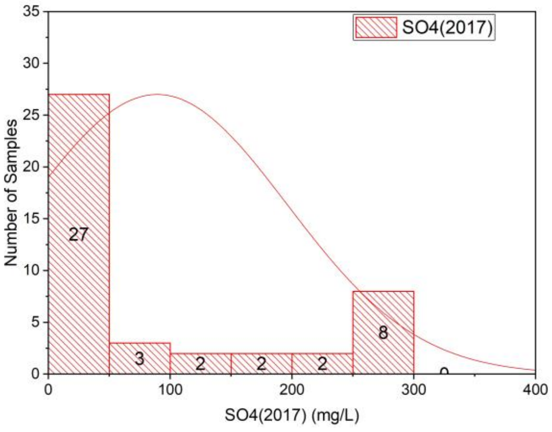


Fig. 5.2.1.82 Empirical probability distribution of Sulphate concentration in Groundwater samples (in year 2017)

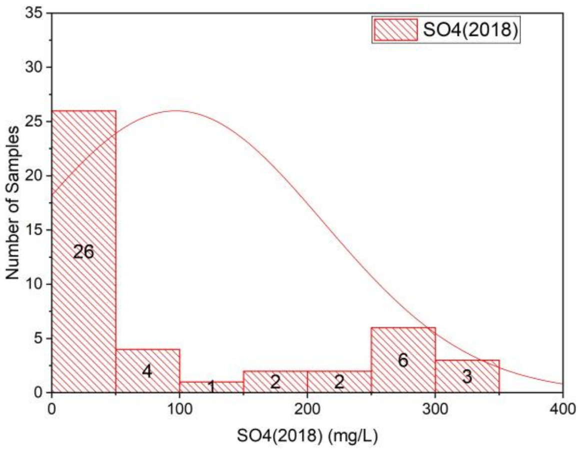


Fig. 5.2.1.83 Empirical probability distribution of Sulphate concentration in Groundwater samples (in year 2018)

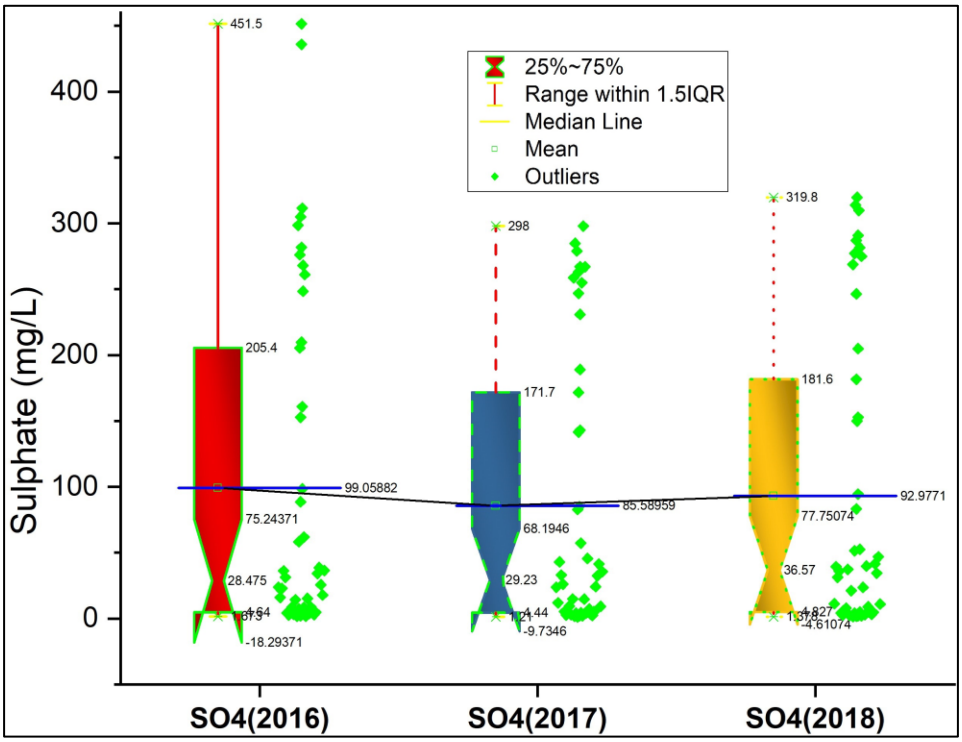
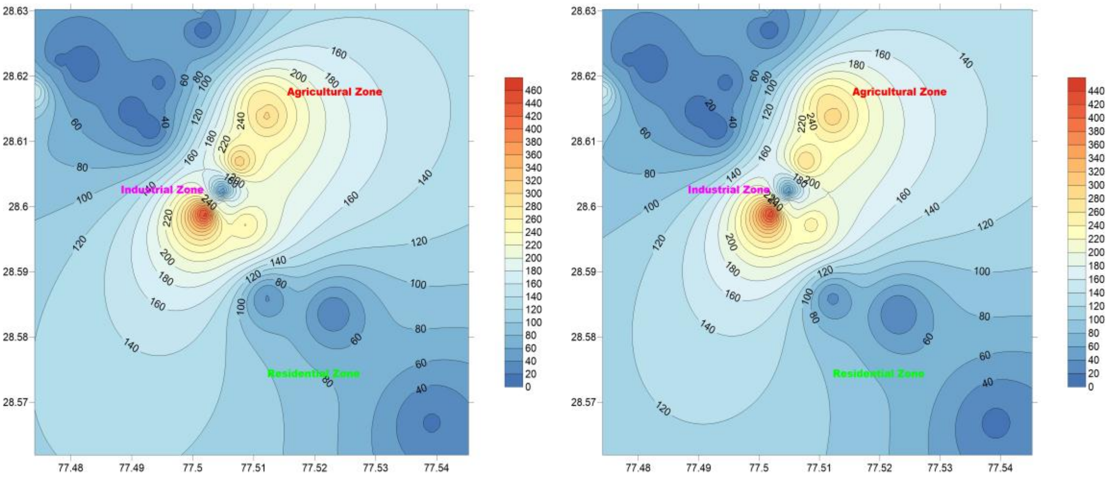
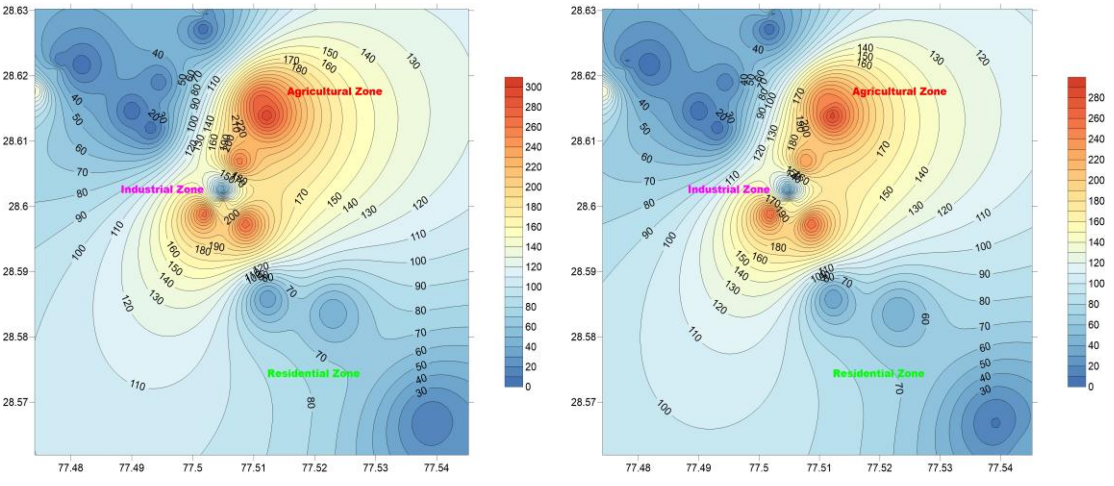


Fig. 5.2.1.84 Box and Whisker plot of Sulphate concentration in Groundwater samples during study period (2016-2018)



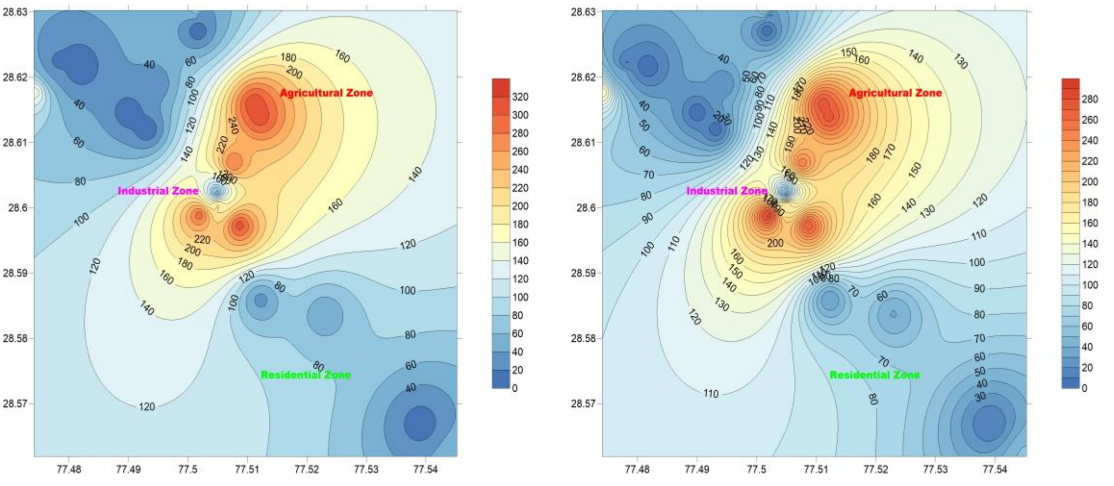
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.1.85 Spatial distribution of Sulphate in Groundwater samples during study period (2016-2018)

5.2.1.18 Ammonia

In environment ammonia can found in ionized (NH_4^+) or unionized form (NH_3). It enters the environment through metabolism in humans, agricultural activities and industrial effluents. Presence of ammonia in water indicates the microbial contamination of water. Naturally small amount of ammonia is present in groundwater (0.2 to 3 mg/L) (WHO). There is no direct health hazard of ammonia in drinking water however it can cause formation of nitrite in distribution system. In distribution systems ammonia reacts with chlorine to form chloramines. No health based guideline value of NH_3 in drinking water, is given by WHO however an odour threshold of 1.5 mg/L at alkaline pH and taste threshold of 35 mg/L (as NH_4^+) is proposed. BIS sets an acceptable limit of 0.5 mg/L (as total ammonia) in drinking water with no relaxation.

The results of ammonia analysis of groundwater samples during study period are given in Table – 5.2.1.35 and 5.2.1.36.

The analytical result revealed that range of ammonia in groundwater of study area was 0.04 to 0.92 mg/L. The minimum concentration of ammonia was analysed in post-monsoon samples of Sadopur water quality station in year 2017. Badhpura water quality station showed maximum concentration of ammonia in groundwater. During 2016 the variation in ammonia concentration of groundwater was from 0.04 to 0.87 mg/L with a mean value of 0.21 mg/L while, in 2017 it ranged from a minimum of 0.04 mg/L to a maximum of 0.68 mg/L. It was observed that values ranged from 0.05 to 0.92 mg/L during 2018. In year 2016 it was found maximum at Bisrakh water quality station and in year 2017 the minimum ammonia concentration was observed at Sadopur water quality station and maximum at Badhpura station with a mean of 0.14 ± 0.12 mg/L. In 2018 it was found maximum at Badhpura station and minimum at Bishnuli water quality station with a mean of 0.161 ± 0.167 mg/L.

Table – 5.2.1.35 Seasonal Variation in Ammonia concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	0.11	0.09	0.10	19.1%	24.4%	14.7%
			Post-monsoon	0.09	0.07	0.08			
	S2	Duryai	Pre-monsoon	0.16	0.10	0.10	9.3%	11.0%	20.4%
			Post-monsoon	0.15	0.09	0.08			
	S3	Duryai	Pre-monsoon	0.11	0.09	0.11	16.8%	7.8%	19.4%
			Post-monsoon	0.09	0.08	0.09			
	S4	Talabpur	Pre-monsoon	0.09	0.07	0.10	13.2%	10.0%	15.5%
			Post-monsoon	0.08	0.06	0.09			
Industrial	S5	Bisrakh Road	Pre-monsoon	0.87	0.09	0.11	0.6%	-22.2%	0.9%
			Post-monsoon	0.87	0.11	0.11			
	S6	Bisrakh Road	Pre-monsoon	0.09	0.12	0.14	1.1%	8.3%	7.1%
			Post-monsoon	0.09	0.11	0.13			
	S7	Bisrakh Road	Pre-monsoon	0.38	0.26	0.27	5.3%	3.8%	22.2%
			Post-monsoon	0.36	0.25	0.21			
	S8	Bisrakh Road	Pre-monsoon	0.10	0.09	0.10	1.0%	3.3%	14.4%
			Post-monsoon	0.10	0.09	0.08			
	S9	Bisrakh Road	Pre-monsoon	0.04	0.06	0.07	0.0%	15.0%	13.8%
			Post-monsoon	0.04	0.05	0.06			
	S10	Khera Dharampura	Pre-monsoon	0.11	0.11	0.14	-12.4%	11.8%	6.6%
			Post-monsoon	0.13	0.10	0.13			
	S11	Bishnuli	Pre-monsoon	0.07	0.06	0.06	14.5%	15.0%	16.4%
			Post-monsoon	0.06	0.05	0.05			
	S12	Achheja	Pre-monsoon	0.27	0.35	0.34	22.2%	8.6%	5.9%
			Post-monsoon	0.21	0.32	0.32			
	S13	Achheja	Pre-monsoon	0.18	0.17	0.21	16.7%	17.6%	4.8%
			Post-monsoon	0.15	0.14	0.20			
	S14	Dujana	Pre-monsoon	0.13	0.11	0.16	11.2%	20.9%	15.1%
			Post-monsoon	0.12	0.09	0.14			
	S15	Dujana	Pre-monsoon	0.14	0.11	0.12	7.1%	9.1%	16.7%
			Post-monsoon	0.13	0.10	0.10			
	S16	Dujana	Pre-monsoon	0.11	0.11	0.13	9.1%	18.2%	15.4%
			Post-monsoon	0.10	0.09	0.11			
	S17	Dujana	Pre-monsoon	0.23	0.22	0.24	4.3%	4.5%	20.8%
			Post-monsoon	0.22	0.21	0.19			
	S18	Badalpur	Pre-monsoon	0.11	0.12	0.14	9.1%	16.7%	21.4%
			Post-monsoon	0.10	0.10	0.11			
Residential	S19	Sadopur	Pre-monsoon	0.08	0.05	0.06	11.3%	22.0%	-13.6%
			Post-monsoon	0.07	0.04	0.07			
	S20	Dairy Maccha	Pre-monsoon	0.69	0.11	0.12	10.4%	4.5%	13.4%
			Post-monsoon	0.62	0.11	0.10			
	S21	Dhoom Manikpur	Pre-monsoon	0.06	0.08	0.08	2.7%	21.3%	10.4%
			Post-monsoon	0.06	0.06	0.07			
	S22	Badhpura	Pre-monsoon	0.75	0.41	0.92	33.3%	-65.9%	15.2%
			Post-monsoon	0.50	0.68	0.78			

Table – 5.2.1.36 Statistical Summary of Ammonia (in mg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.04	Bisrakh Road	0.04	Bisrakh Road	0.5	Sadopur	0.4	Sadopur	0.06	Sadopur	0.05	Bishnuli
Max.	0.87	Bisrakh Road	0.87	Bisrakh Road	0.41	adhpura	0.68	Badhpura	0.92	Badhpura	0.78	Badhpura
Mean	0.22		0.20		0.14		0.14		0.173		0.149	
St. Dev.	0.24		0.21		0.09		0.14		0.181		0.154	

In residential zone, few samples of Dairy Maccha (in year 2016) and Badhpura (in all three years) exceeded the acceptable limit of 0.5 mg/L while rest of the samples were suitable for drinking. In industrial zone, the value of ammonia ranged from 0.04 to 0.87 mg/L with a mean value of 0.16 mg/L. Groundwater of Bisrakh Road water quality station have ammonia concentration higher than the 0.5 mg/L. At this station in year 2016, ammonia content of groundwater was much higher than the acceptable limit of BIS. Maximum mean concentration of ammonia was obtained from residential zone of study area. The results of analysis indicate that groundwater of residential zone of study area was partially fit for drinking. After analyzing the results on the basis of different zone, it was found that groundwater of agricultural zone was fit for drinking (0.06 to 0.16 mg/L).

Results of ammonia analysis in groundwater samples, throughout the study period (2016, 2017 & 2018) at all twenty-two water quality stations, are presented through distribution plot & Box-Whisker plot (Fig. 5.2.1.86, 5.2.1.87, 5.2.1.88 & 5.2.1.89). Spatial distribution plot of ammonia in analysed groundwater samples is presented in Fig. 5.2.1.90. Residential zone has higher content of ammonia in groundwater.

In majority of samples, ammonia content decreased after monsoon season. On the basis of acceptable limit of ammonia given by BIS, 6.8% of samples were not safe for drinking. Bundela et al., (2012) studied the groundwater quality near to municipal solid waste dumping sites in Jabalpur and recorded a range of ND to 4.3 mg/L of ammonia. Lal et al., (2014) recorded a range of 0.1 to 0.52 mg/L of ammonia in groundwater of Bhachau-Kachchh, Gujarat, with a mean value of 0.13 mg/L.

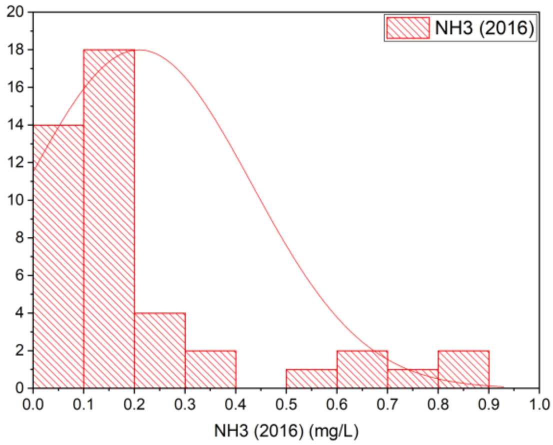


Fig. 5.2.1.86 Empirical probability distribution of Ammonia concentration in Groundwater samples (in year 2016)

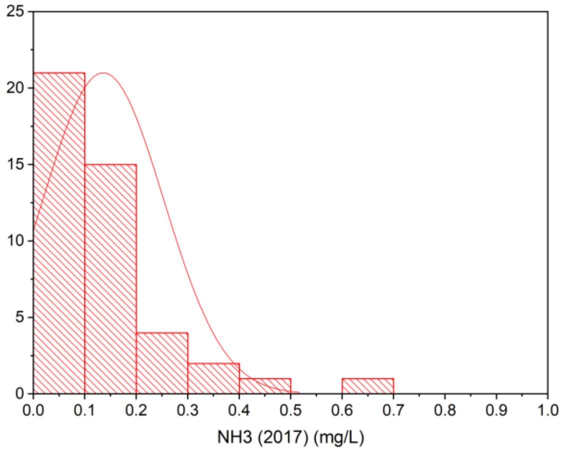


Fig. 5.2.1.87 Empirical probability distribution of Ammonia concentration in Groundwater samples (in year 2017)

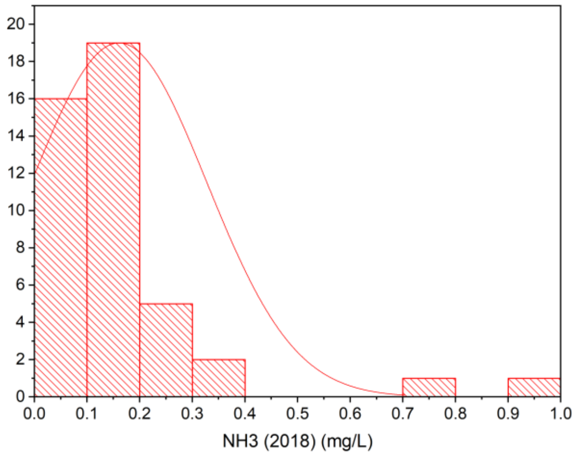


Fig. 5.2.1.88 Empirical probability distribution of Ammonia concentration in Groundwater samples (in year 2018)

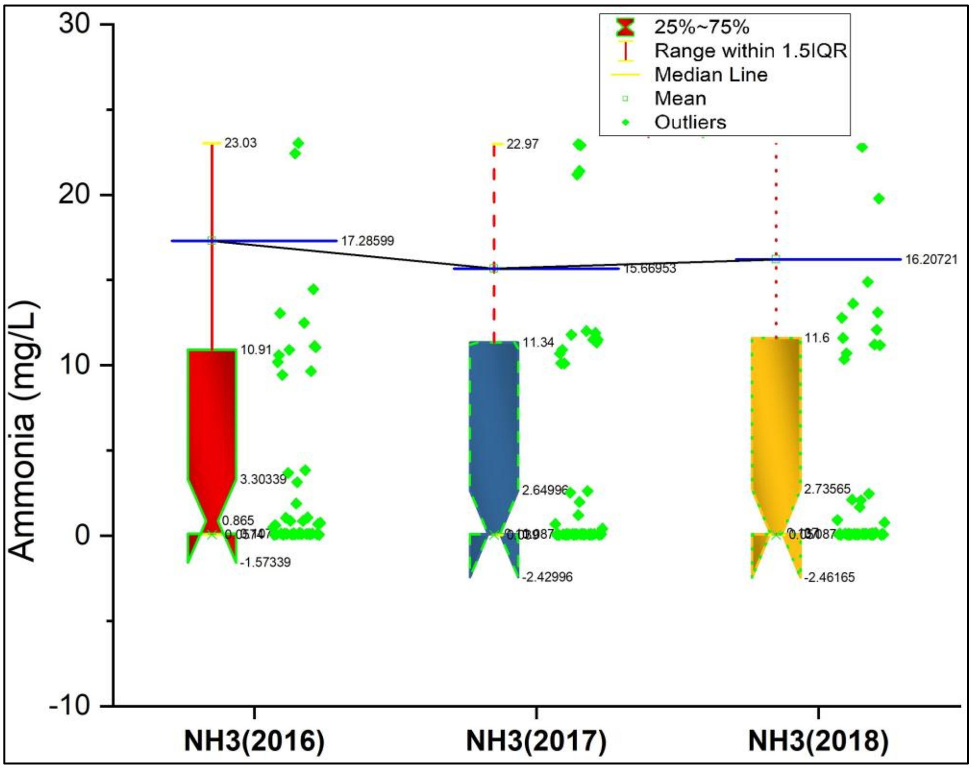
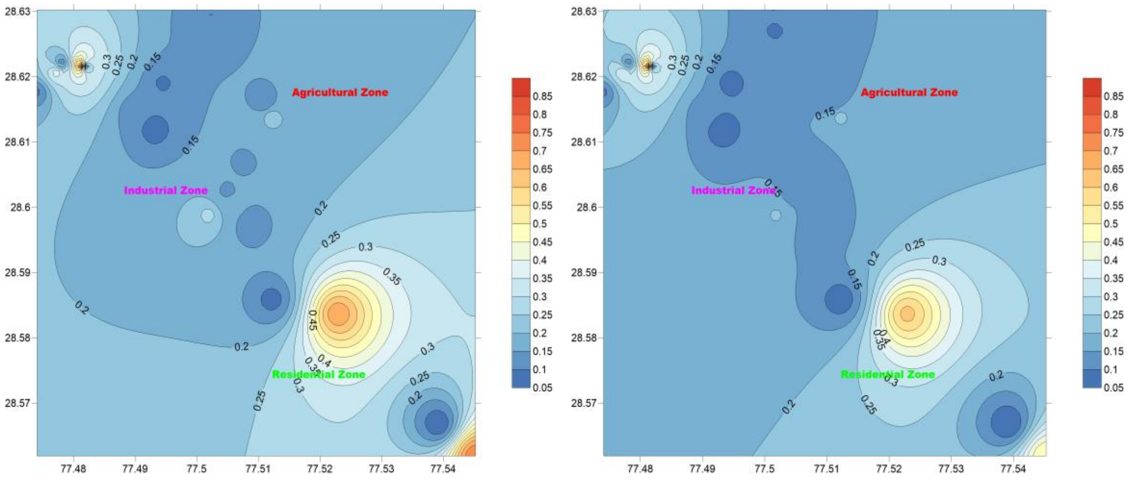
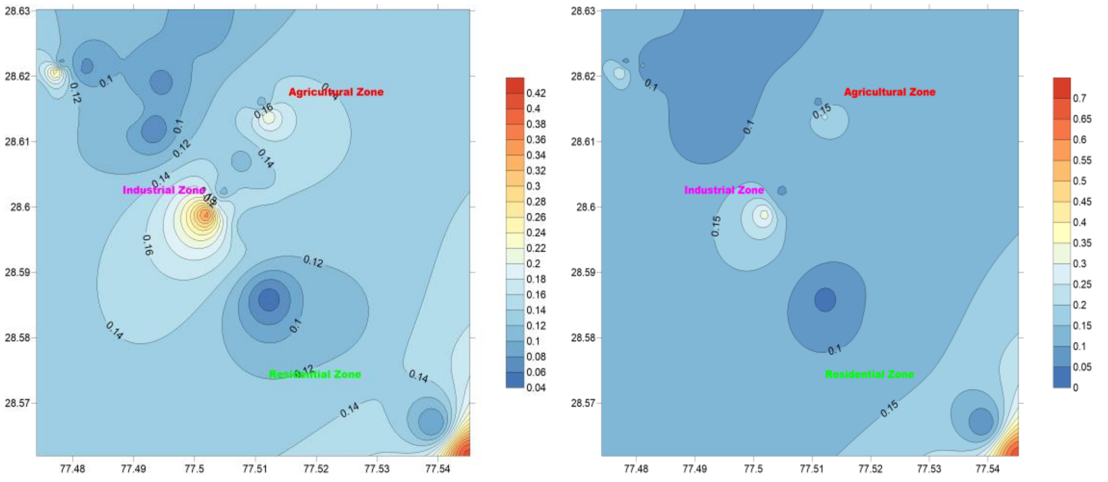


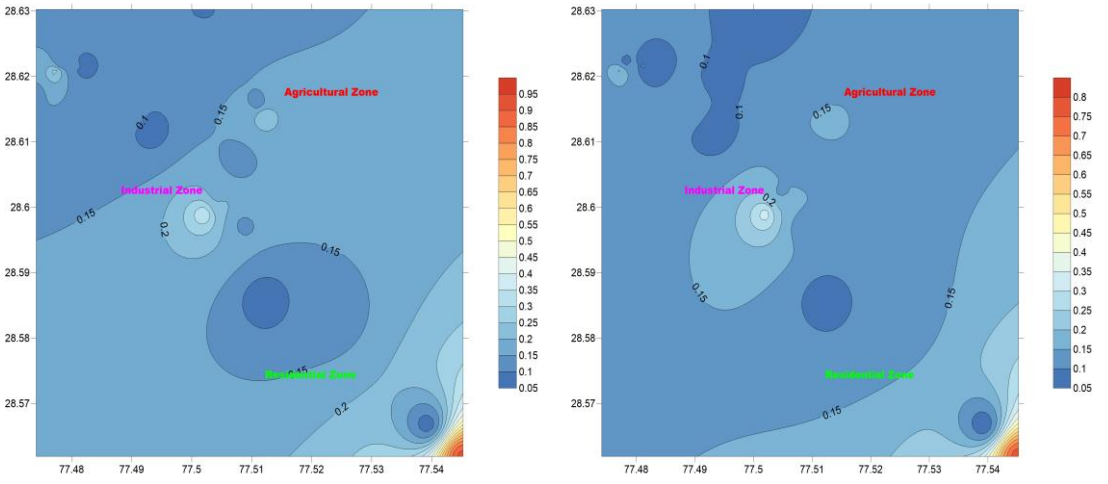
Fig. 5.2.1.89 Box and Whisker plot of Ammonia concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.1.90 Spatial distribution of Ammonia in Groundwater samples during study period (2016-2018)

5.2.2 TOXICITY OF HEAVY METALS

Heavy metals are the metals whose atomic weights between 63.5 & 200.6 and density greater than 5 gm/cm (Srivastava & Majumder, 2008). Metals occupy a major proportion of the total identified elements and rest is constituted by non-metals and metalloids. Heavy metals are those metals having relatively higher density than water. In spite of being a metalloid, arsenic is also considered as a heavy metal. These metals cause toxicity in living beings even a trace amount is present inside the living body. Many metals form bonds with sulphydryl groups of enzymes and inhibits activity of enzyme. (Jung, 2001; Liu et al., 2014). Heavy metals once entered into the food chain, remain there until reach upto the toxic level (Abah et al., 2013). Some heavy metals, essential for the living organisms in small quantities, are called essential trace element e.g. iron, cobalt, zinc, copper. But excessive intake of these metals causes serious health problems. Rapid industrialization & unplanned urbanization causes elevated content of metals in the environment and causes risk of health diseases (Rajasulochana & Preethy, 2016). Heavy metals are present in the industrial effluent of many industries such as metal plating, fertilizer industries, tannaries, cement factories, battery industries, textile, dying etc. The effluent from the industries are directly or indirectly disposed into the environment without proper treatment. Due the process of time, metals present in the effluent mix with water aquifers. These metals are non-biodegradable and remain in aquifers for a long time (Karthika et al., 2015). Due to high solubility of heavy metals in aqueous medium, these metals can easily be entered into the body of living organisms (Barakat, 2011).

5.2.2.1 Arsenic

Arsenic (As) is present everywhere in ecosystem in varying concentration. It is widely present in every component of environment like soil, atmosphere, rocks, water bodies and living organisms. Both natural processes (biological activities, weathering processes and volcanic eruptions) and anthropological activities contribute to arsenic content in environment (Kinniburg & Smedley, 2001; Jayasumana et al., 2015; Patel et al., 2017). Arsenic is present in environment in both inorganic (trivalent arsenite & pentavalent arsenate) and organic form (monomethyl arsonate, MMA & dimethyl arsinate, DMA). Inorganic form of arsenic has higher toxicity than organic form of arsenic. Under natural circumstances, arsenic content of environment has no adverse impact but due to human activities, a significant amount of arsenic has been added to the environment. Various mining activity, use of arsenical pesticides/herbicides/crop desiccants, combustion of fossil fuels, the use of arsenic as a supplementary food for poultry and effluent of different industries are major source of arsenic in ecosystem (Smedley & Kinniburg, 2002; Bhattacharya et al., 2011). Although recently, the usage of arsenical products has been declined but the adverse impact of utilization of arsenic rich products on environment will remain for a long time (Faust et al., 1983; Hong et al., 2017). According to Indian standards for drinking Water (BIS 10500: 2012) acceptable limit of arsenic, is 10 µg/L and a permissible limit of 50 µg/L. WHO sets standard value of 10 µg/L for arsenic in potable water.

Analytical results of arsenic in all twenty-two groundwater samples are given in Table – 5.2.2.1 and 5.2.2.2.

The concentration of arsenic varied from 0.518 to 12.563 µg/L with a mean value of 3.354 ± 2.753 µg/L during the study period. The highest concentration 12.563 µg/L was recorded at Bishnuli water quality station in pre-monsoon samples of year 2017 and minimum concentration 0.518 µg/L was at Sadopur water quality station in post-monsoon samples of year 2017. The high content of arsenic in groundwater sample of Bishnuli may be due to the presence of a nearby drainage coming from an adhesive factory. In year 2016, arsenic concentration of groundwater of study area ranged from 0.625 µg/L (in post-monsoon sample of Sadopur station) to 12.563 µg/L (in pre-monsoon sample of Bishnuli station). In year 2017, its concentration was 0.518 µg/L (in post-monsoon sample of Sadopur station) to 8.954 µg/L (in pre-monsoon sample of Dujana station). In year 2018, maximum concentration of arsenic (9.277 µg/L) was analysed in pre-monsoon sample of Dujana station and minimum (0.673 µg/L) was analysed in post-monsoon samples of Sadopur station.

Agricultural zone of study area showed a mean of 2.27 µg/L of arsenic with a minimum value of 1.352 µg/L and maximum of 3.101 µg/L. Residential zone of study area have arsenic concentration ranged between 0.518 µg/L and 2.841 µg/L. In both the zone, arsenic concentration of groundwater was within the standard value given by BIS and WHO. However in industrial zone, arsenic concentration varied from 0.815 to 12.563 µg/L. The upper limit of range exceeded the acceptable limit of BIS and standard limit of WHO. The results of study indicate anthropological sources of arsenic distribution in groundwater of study area.

Table – 5.2.2.1 Seasonal Variation in Arsenic concentration (in µg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from pre-monsoon to post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	2.063	2.338	2.453	4.0%	9.9%	9.6%
			Post-monsoon	1.981	2.106	2.218			
	S2	Duryai	Pre-monsoon	1.972	2.421	2.877	21.6%	8.2%	14.1%
			Post-monsoon	1.546	2.223	2.471			
	S3	Duryai	Pre-monsoon	3.101	2.638	2.772	7.1%	3.3%	12.0%
			Post-monsoon	2.881	2.551	2.438			
	S4	Talabpur	Pre-monsoon	2.617	1.584	1.857	8.0%	14.6%	13.2%
			Post-monsoon	2.408	1.352	1.612			
Industrial	S5	Bisrakh Road	Pre-monsoon	1.781	1.85	1.941	6.5%	4.3%	14.4%
			Post-monsoon	1.665	1.771	1.662			
	S6	Bisrakh Road	Pre-monsoon	1.835	1.551	1.899	8.3%	3.9%	17.8%
			Post-monsoon	1.682	1.491	1.561			
	S7	Bisrakh Road	Pre-monsoon	8.812	8.05	8.412	10.2%	1.7%	3.0%
			Post-monsoon	7.916	7.915	8.156			
	S8	Bisrakh Road	Pre-monsoon	3.651	1.993	5.447	23.0%	21.4%	40.7%
			Post-monsoon	2.812	1.566	3.231			
	S9	Bisrakh Road	Pre-monsoon	4.663	1.743	3.331	10.2%	36.5%	12.6%
			Post-monsoon	4.186	1.106	2.912			
	S10	Khera Dharampura	Pre-monsoon	2.415	1.983	1.218	9.6%	18.1%	8.5%
			Post-monsoon	2.182	1.625	1.115			
	S11	Bishnuli	Pre-monsoon	12.563	6.821	6.414	18.6%	7.3%	4.0%
			Post-monsoon	10.231	6.326	6.157			
	S12	Achheja	Pre-monsoon	1.131	0.927	1.143	15.8%	12.1%	3.1%
			Post-monsoon	0.952	0.815	1.108			
	S13	Achheja	Pre-monsoon	2.387	1.352	3.821	17.7%	8.3%	12.7%
			Post-monsoon	1.964	1.24	3.336			
	S14	Dujana	Pre-monsoon	6.118	4.741	5.617	5.5%	10.2%	8.7%
			Post-monsoon	5.784	4.257	5.127			
	S15	Dujana	Pre-monsoon	8.328	7.945	9.277	7.9%	9.8%	8.2%
			Post-monsoon	7.667	7.168	8.515			
	S16	Dujana	Pre-monsoon	12.317	8.954	9.268	15.2%	5.2%	3.6%
			Post-monsoon	10.441	8.486	8.931			
	S17	Dujana	Pre-monsoon	2.137	1.954	3.175	10.2%	17.2%	2.3%
			Post-monsoon	1.918	1.618	3.101			
	S18	Badalpur	Pre-monsoon	2.518	2.185	3.354	12.0%	10.5%	13.0%
			Post-monsoon	2.216	1.955	2.918			
Residential	S19	Sadopur	Pre-monsoon	0.892	0.697	0.734	29.9%	25.7%	8.3%
			Post-monsoon	0.625	0.518	0.673			
	S20	Dairy Maccha	Pre-monsoon	0.842	1.165	1.117	10.3%	7.7%	9.3%
			Post-monsoon	0.755	1.075	1.013			
	S21	Dhoom Manikpur	Pre-monsoon	2.562	1.625	2.349	12.8%	18.9%	9.9%
			Post-monsoon	2.235	1.318	2.117			
	S22	Badhpura	Pre-monsoon	2.251	1.524	2.841	10.7%	24.8%	25.6%
			Post-monsoon	2.011	1.146	2.115			

Table – 5.2.2.2 Statistical Summary of Arsenic (in µg/L) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	0.842	Dairy Maccha	0.625	Sadopur	0.697	Sadopur	0.518	Sadopur	0.734	Sadopur	0.673	Sadopur
Max.	12.563	Bishnuli	10.441	Dujana	8.954	Dujana	8.486	Dujana	9.277	Dujana	8.931	Dujana
Mean	3.953		3.457		3.002		2.710		3.696		3.295	
St. Dev.	3.473		2.970		2.531		2.440		2.605		2.488	

Percent change in arsenic concentration from pre-monsoon to post-monsoon season showed dilution of ground aquifers after rainfall. Chaturvedi et al., (2018) also reported decrease in arsenic concentration from pre-monsoon (3.05 µg/L) to post-monsoon season (1.93 µg/L).

The empirical probability distribution plots with respect to arsenic at all the twenty-two water quality stations of the study area during study period (2016, 2017 & 2018) are shown in Fig. 5.2.2.1, 5.2.2.2 and 5.2.2.3 respectively. Box and Whisker plot of arsenic concentration in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.2.4. The mean value of arsenic in year 2016, 2017 and 2018 were 3.705, 2.856 and 3.496 µg/L respectively. During the study period, Dujana and Bishnuli water quality station showed maximum concentration of arsenic. These stations were in industrial zone of study area hence it can be concluded that percolation of metal from industrial effluents was responsible for elevated level of arsenic in underground aquifers. The distribution pattern of arsenic in underground water of study area, during study period, is presented in Fig. 5.2.2.5. Arsenic contamination in groundwater of industrial zone is clearly visible in contour map of study area.

Many anthropogenic sources which contribute to the arsenic content of natural water are the extraction and fusion of metals, the combustion of fossils fuels, the preservation of wood, the production and application of pesticides (lead arsenate (PbAsO4), calcium arsenate (CaAsO4), magnesium arsenate (MgAsO4), arsenate (ZnAsO4) and arsenite (ZnAsO3) of zinc, etc.), use of commercial fertilizers (phosphate fertilizers), disposal and incineration of municipal and industrial waste. Prolonged consumption of arsenic rich water causes skin diseases (pigmentation &

keratosis), non-malignant lung diseases, gastrointestinal disease (dyspepsia & gastroentritis), peripheral neuritis, perpheral vascular disease (Black foot disease), haematological abnormalities and carcinogenicity (Adhikary & Mandal, 2017). Out of total analysed samples 3% of samples were out of standard value (10 µg/L) of arsenic. These samples were collected from Bishnuli & Dujana water quality station in year 2016. Singh et al., (2011) reported arsenic content (3 to 119 µg/L) of groundwater of Noida metropolitan city of Uttar Pradesh. Kumar et al., (2017) recorded a range of 0.07 to 237 µg/L in groundwater of Chhaprola industrial area of Gautam Buddha Nagar of Uttar Pradesh. They analysed that all the collected samples (except one) were within the standard limit of WHO and BIS. Kumar et al., 2019 reported that 30% of analysed samples of Saharanpur district of Uttar Pradesh exceeded the standard value of arsenic of BIS and WHO. Similar type of studies were done by many researchers (Sekhon & Singh, 2013 in Patiala district of Punjab; Kumar et al., 2015 in Fazilka district of Punjab; Kumar et al., 2016 in middle gangetic plain of Bihar; Patel et al., 2017 in Rajnandgaon District of Chhattisgarh).

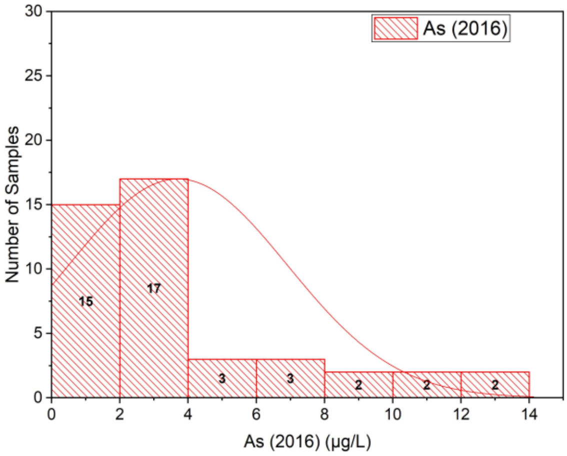


Fig. 5.2.2.1 Empirical probability distribution of Arsenic concentration in Groundwater samples (in year 2016)

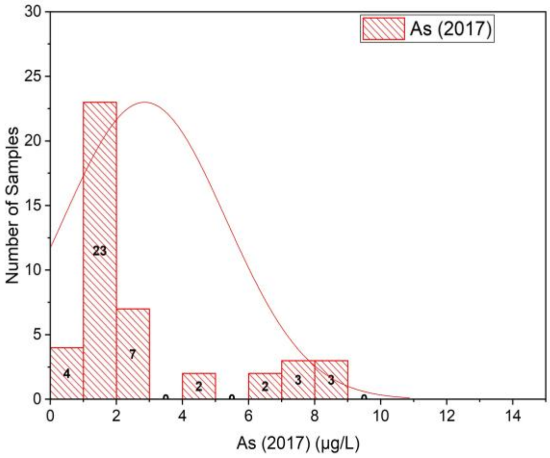


Fig. 5.2.2.2 Empirical probability distribution of Arsenic concentration in Groundwater samples (in year 2017)

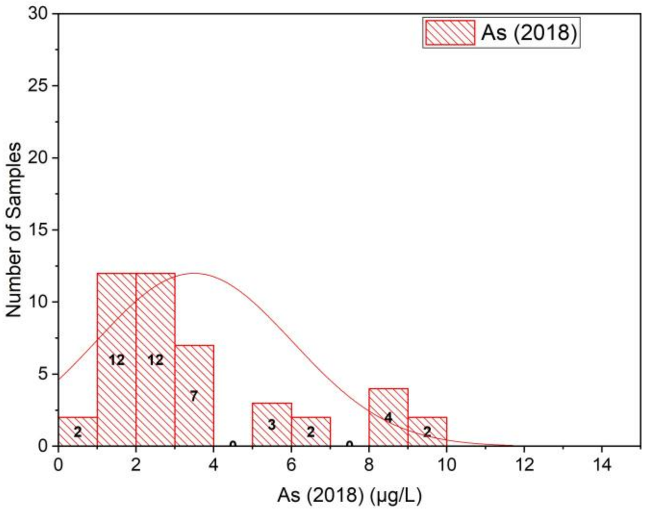


Fig. 5.2.2.3 Empirical probability distribution of Arsenic concentration in Groundwater samples (in year 2017)

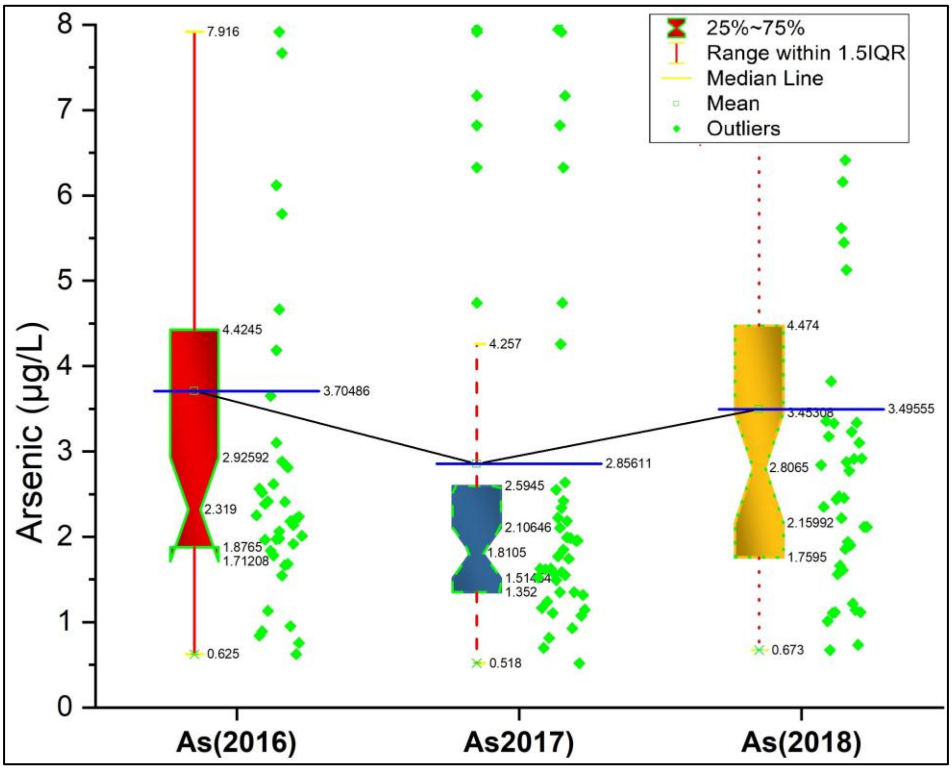
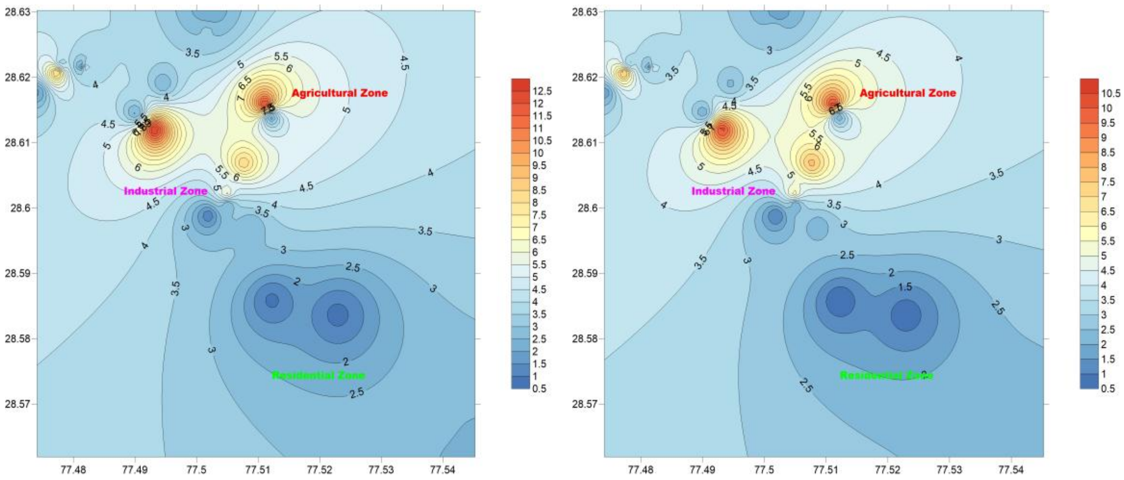
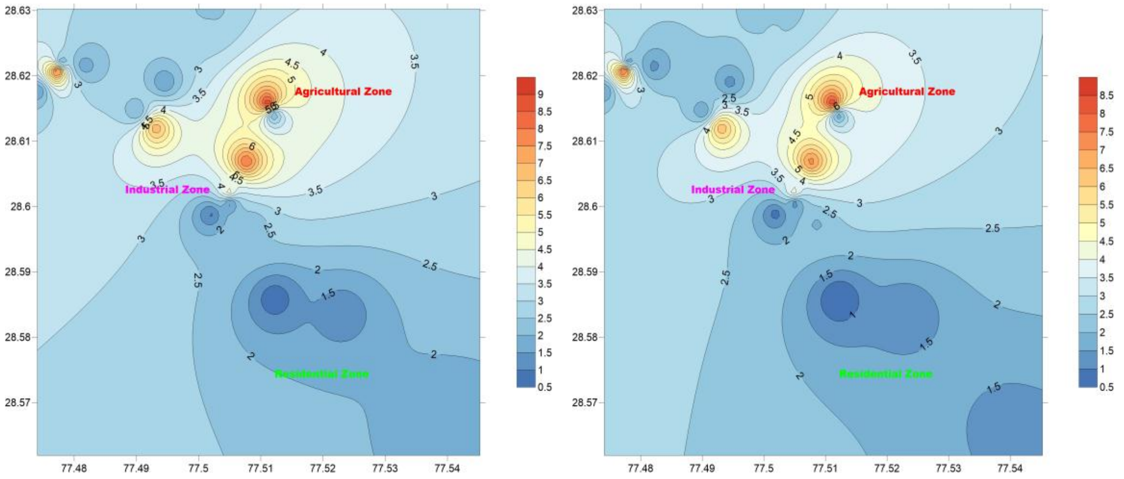


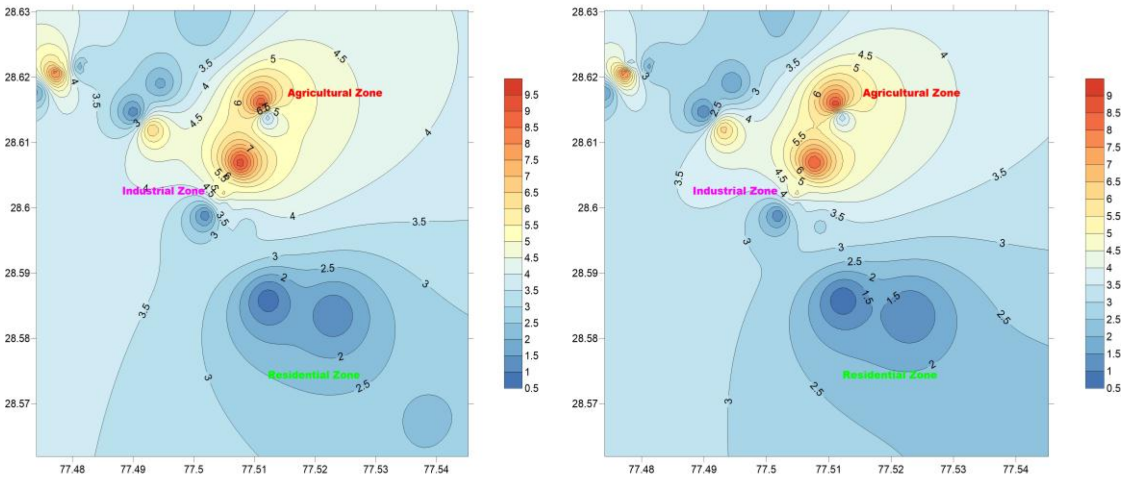
Fig. 5.2.2.4 Box and Whisker plot of Arsenic concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) **2016 (Post-Monsoon)**



2017 (Pre-Monsoon) **2017 (Post-Monsoon)**



2018 (Pre-Monsoon) **2018 (Post-Monsoon)**

Fig. 5.2.2.5 Spatial distribution of Arsenic in Groundwater samples during study period (2016-2018)

5.2.2.2 Cadmium

In the earth's crust, cadmium is uniformly distributed in association with zinc, lead and copper ores but normally estimated to be present at a mean concentration of 0.15 to 0.2 mg/kg. A relatively lesser amount of cadmium is found in water bodies in combined forms such as carbonates, hydroxides, chlorides or sulphates (Morrow, 2001). Even in contaminated aquifers, cadmium concentration is very less and sometimes not detectable. Cadmium is a highly toxic metal and is a well known carcinogen for human beings. Few recent studies also identified the toxicity of cadmium to skeletal system of humans. A very small amount of cadmium can adversely affect human renal system. On the basis of toxicity of cadmium, BIS (2012) laid the desirable limit of 3 µg/L cadmium in drinking water without any relaxation. WHO, (2017) also propose a guideline value of 3 µg/L of cadmium in drinking water. Untreated effluent of many industries; textile industry, paint industry, cadmium-stabilized plastics, battery industry, plating industry etc., is contaminating natural water (Rani et al., 2014). Cadmium toxicity in textile mills effluents was studied by Bhardwaj et al., (2014).

During study period, analytical results of cadmium in all twenty-two groundwater samples are given in Table – 5.2.2.3 and 5.2.2.4.

The concentration of cadmium ranged from 0.004 to 5.997 µg/L with the mean value of 1.195 µg/L in the whole study period. Minimum value of 0.004 µg/L was recorded from Duryai water quality station in post-monsoon sample of year 2017 and maximum value of 5.997 µg/L was recorded from Dujana water quality station in pre-monsoon sample of year 2018. During 2016 the variation in cadmium content of groundwater was from 0.008 to 5.447 µg/L with a mean value of 1.341 ± 1.570 while, in 2017 it ranged from a minimum of 0.004 µg/L to a maximum of 4.825 µg/L. It was observed that values ranged from 0.008 to 5.997 µg/L during 2018. In year 2016 it was found maximum at Dujana water quality station and in year 2017 the minimum cadmium concentration was observed at Duryai water quality station and maximum at Dujana with a mean of 1.062 ± 1.242 µg/L. In 2018 it was found maximum at Dujana site and minimum at Duryai water quality station with a mean of 1.183 ± 1.520 µg/L.

Table – 5.2.2.3 Seasonal Variation in Cadmium concentration (in µg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	0.022	0.005	0.035	27.27%	20.00%	11.43%
			Post-monsoon	0.016	0.004	0.031			
	S2	Duryai	Pre-monsoon	0.014	0.017	0.02	42.86%	-5.88%	5.00%
			Post-monsoon	0.008	0.018	0.019			
	S3	Duryai	Pre-monsoon	0.038	0.007	0.009	42.11%	14.29%	11.11%
			Post-monsoon	0.022	0.006	0.008			
	S4	Talabpur	Pre-monsoon	0.158	0.015	0.112	25.32%	6.67%	1.79%
			Post-monsoon	0.118	0.014	0.11			
Industrial	S5	Bisrakh Road	Pre-monsoon	1.02	0.166	0.266	7.45%	10.84%	25.19%
			Post-monsoon	0.944	0.148	0.199			
	S6	Bisrakh Road	Pre-monsoon	0.846	1.135	0.923	5.91%	19.47%	9.86%
			Post-monsoon	0.796	0.914	0.832			
	S7	Bisrakh Road	Pre-monsoon	0.633	0.566	0.759	17.85%	3.18%	11.07%
			Post-monsoon	0.52	0.548	0.675			
	S8	Bisrakh Road	Pre-monsoon	0.314	0.764	0.188	32.17%	6.81%	5.85%
			Post-monsoon	0.213	0.712	0.177			
	S9	Bisrakh Road	Pre-monsoon	0.144	0.117	0.119	3.47%	9.40%	15.13%
			Post-monsoon	0.139	0.106	0.101			
	S10	Khera Dharampura	Pre-monsoon	1.08	0.129	0.224	7.41%	6.98%	1.79%
			Post-monsoon	1	0.12	0.22			
	S11	Bishnuli	Pre-monsoon	0.048	0.028	0.114	18.75%	3.57%	1.75%
			Post-monsoon	0.039	0.027	0.112			
	S12	Achheja	Pre-monsoon	0.886	0.113	0.556	11.85%	-1.77%	12.23%
			Post-monsoon	0.781	0.115	0.488			
	S13	Achheja	Pre-monsoon	0.288	0.068	0.068	17.36%	19.12%	10.29%
			Post-monsoon	0.238	0.055	0.061			
	S14	Dujana	Pre-monsoon	5.447	4.825	4.992	5.73%	30.69%	9.82%
			Post-monsoon	5.135	3.344	4.502			
	S15	Dujana	Pre-monsoon	2.65	3.115	2.344	27.06%	7.16%	10.28%
			Post-monsoon	1.933	2.892	2.103			
	S16	Dujana	Pre-monsoon	5.322	3.668	5.997	13.92%	18.46%	14.92%
			Post-monsoon	4.581	2.991	5.102			
	S17	Dujana	Pre-monsoon	2.302	1.778	1.007	8.30%	37.40%	0.50%
			Post-monsoon	2.111	1.113	1.002			
	S18	Badalpur	Pre-monsoon	2.118	2.556	2.651	6.14%	14.79%	19.58%
			Post-monsoon	1.988	2.178	2.132			
Residential	S19	Sadopur	Pre-monsoon	1.88	1.443	1.685	6.81%	14.28%	4.63%
			Post-monsoon	1.752	1.237	1.607			
	S20	Dairy Maccha	Pre-monsoon	1.482	1.761	1.882	11.54%	23.40%	18.01%
			Post-monsoon	1.311	1.349	1.543			
	S21	Dhoom Manikpur	Pre-monsoon	3.665	2.559	2.872	18.23%	17.43%	18.70%
			Post-monsoon	2.997	2.113	2.335			
	S22	Badhpura	Pre-monsoon	1.008	0.975	0.943	0.60%	6.56%	2.12%
			Post-monsoon	1.002	0.911	0.923			

Table – 5.2.2.4 Statistical Summary of Cadmium (in µg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.014	Duryai	0.008	Duryai	0.005	Duryai	0.004	Duryai	0.009	Duryai	0.008	Duryai
Max.	5.447	Dujana	5.135	Dujana	4.825	Dujana	3.344	Dujana	5.997	Dujana	5.102	Dujana
Mean	1.426		1.257		1.173		0.951		1.262		1.104	
St. Dev.	1.613		1.432		1.394		1.090		1.645		1.419	

In agricultural zone cadmium concentration varied from 0.004 to 0.158 µg/L with a mean value of 0.034 µg/L. The cadmium content in industrial zone ranged between 0.027 and 5.997 µg/L providing a mean value of 1.378 µg/L. Residential zone of study area also has a wide range of cadmium concentration with a minimum value of 0.911 µg/L and a maximum value of 3.665 µg/L. In residential zone, Badhpura water quality station has minimum concentration of cadmium in groundwater and Dhoom Manikpur station has maximum value.

Higher value of cadmium was noted in pre-monsoon samples and decreased in post-monsoon samples. Two samples (S2 & S12) collected from Duryai and Achheja water quality station in year 2017 have slightly elevated content of cadmium in post-monsoon season. This may be due to the presence of a drain near the source of groundwater sample.

The empirical probability distribution plots of cadmium in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.2.6, 5.2.2.7 and 5.2.2.8 respectively. Box and whisker plot of cadmium level in groundwater showed that a wide range of cadmium concentration was obtained from the analysed samples (Fig. 5.2.2.9). Spatial distribution of cadmium in groundwater of study area is given in Fig. 5.2.2.10. It was found that the samples showing a hike in the cadmium value, were collected mainly from Dujana water quality station and one sample from Dhoom Manikpur water quality station. The waste products released from the CHW Forge industry, where forging and flange was carried out, were responsible for contamination of ground aquifers with cadmium. A pipe manufacturing unit was also running in this area. The effluent of this industry also contaminated the water resources. A cement manufacturing unit -

Ambuja cement Ltd. was present in Dhoom Manikpur. The dumping of industrial wastes of this industry contributed to the cadmium level in ground aquifers.

Out of total analysed sample, nearly 10% of samples crossed the limits of cadmium as set by WHO and BIS. Ullah et al., (2009) reported that a large amount of processed water was dumped by the industry into nearby agricultural lands, ponds, open ditches, rivers, streams and open land. This waste water had various dissolved toxic substances and heavy metals. Percolation of hazardous chemicals from the toxic effluents contaminated potable water supplies. Sekhon & Singh, (2013) reported anthropogenic source of cadmium in groundwater of Patiala district of Punjab. Similar type of study was carried out by Kumar et al., (2015) in Fazilka district of Punjab. Idrees et al., (2018) investigated the cadmium content of groundwater and its toxic effects in four district of west Uttar Pradesh (Shahjehanpur (0.06 ± 0.01 mg/L), Bareilly (0.07 ± 0.01 mg/L), Moradabad (0.06 ± 0.01 mg/L) and Rampur (0.05 ± 0.01).

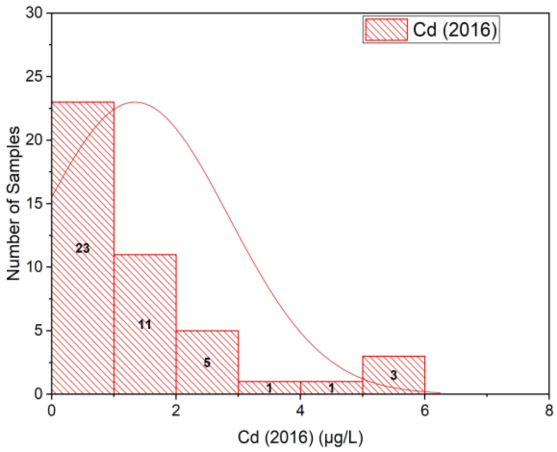


Fig. 5.2.2.6 Empirical probability distribution of Cadmium concentration in Groundwater samples (in year 2016)

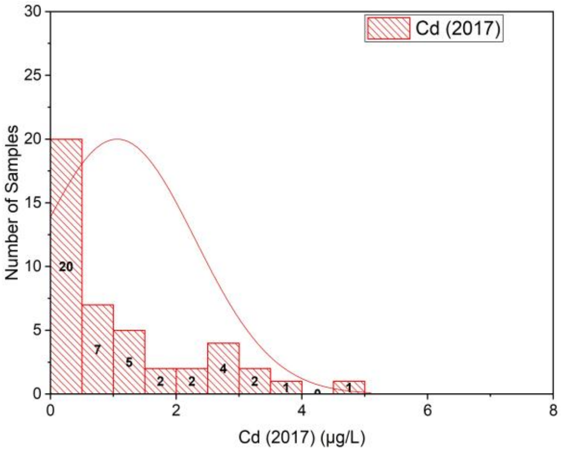


Fig. 5.2.2.7 Empirical probability distribution of Cadmium concentration in Groundwater samples (in year 2017)

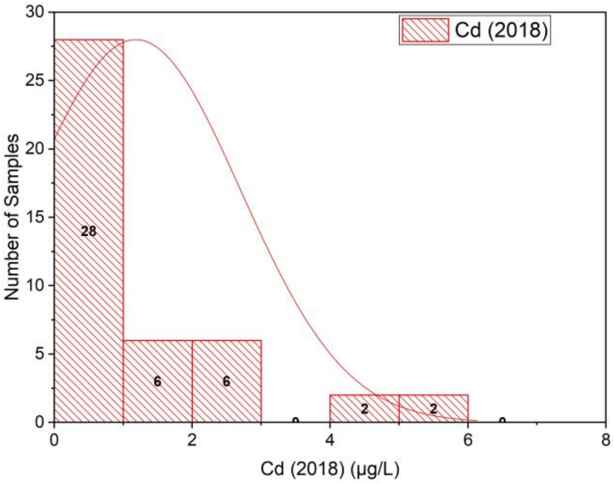


Fig. 5.2.2.8 Empirical probability distribution of Cadmium concentration in Groundwater samples (in year 2018)

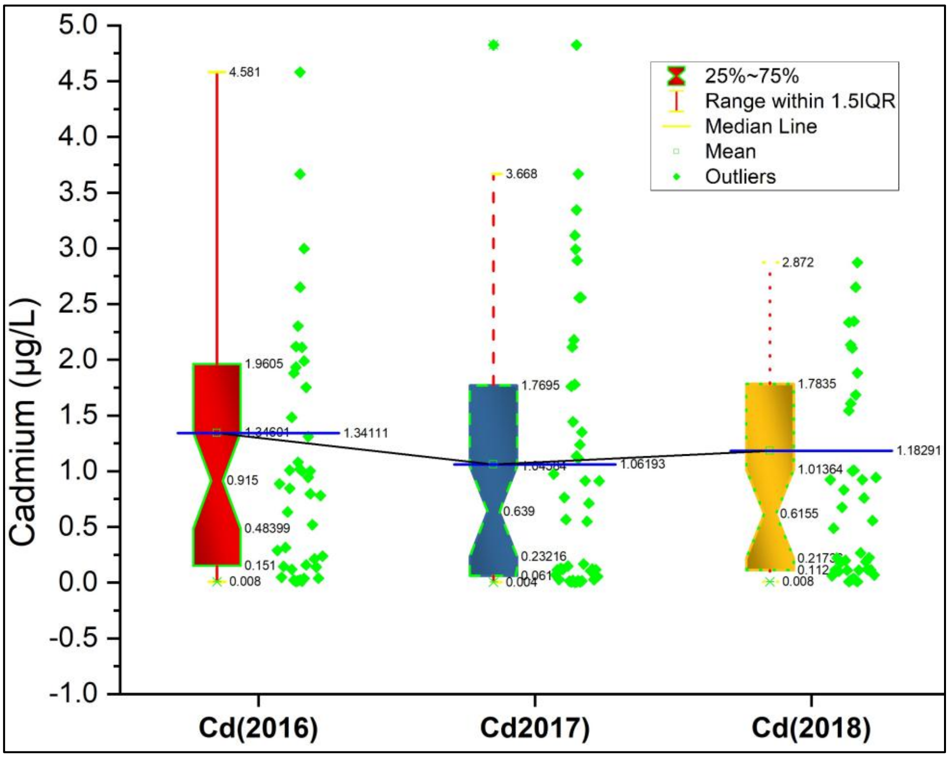
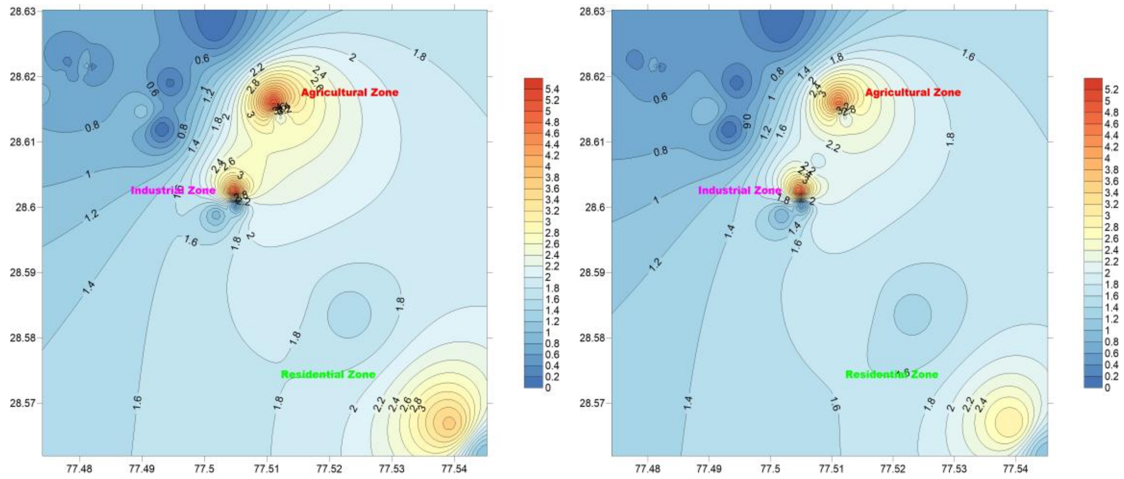
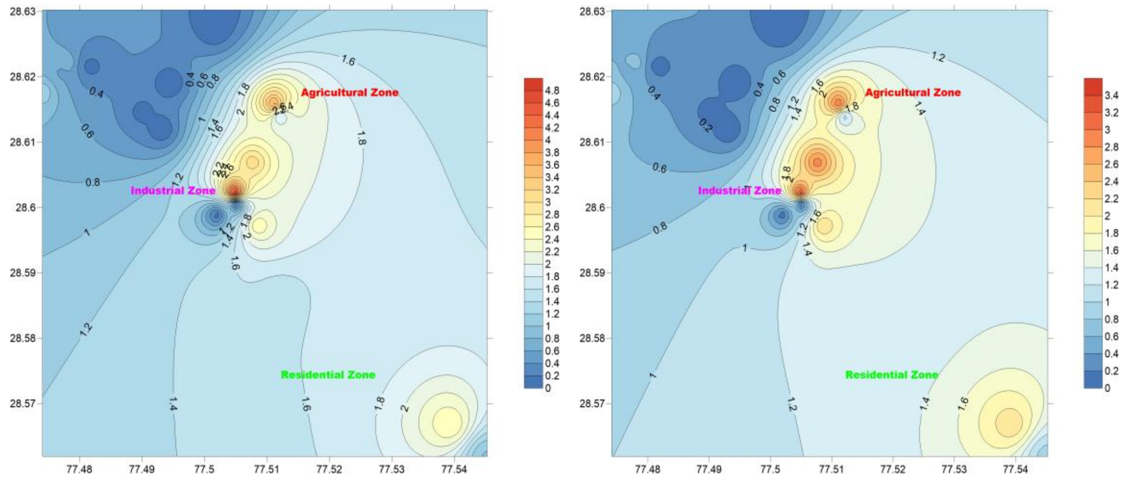


Fig. 5.2.2.9 Box and Whisker plot of Cadmium concentration in Groundwater samples during study period (2016-2018)



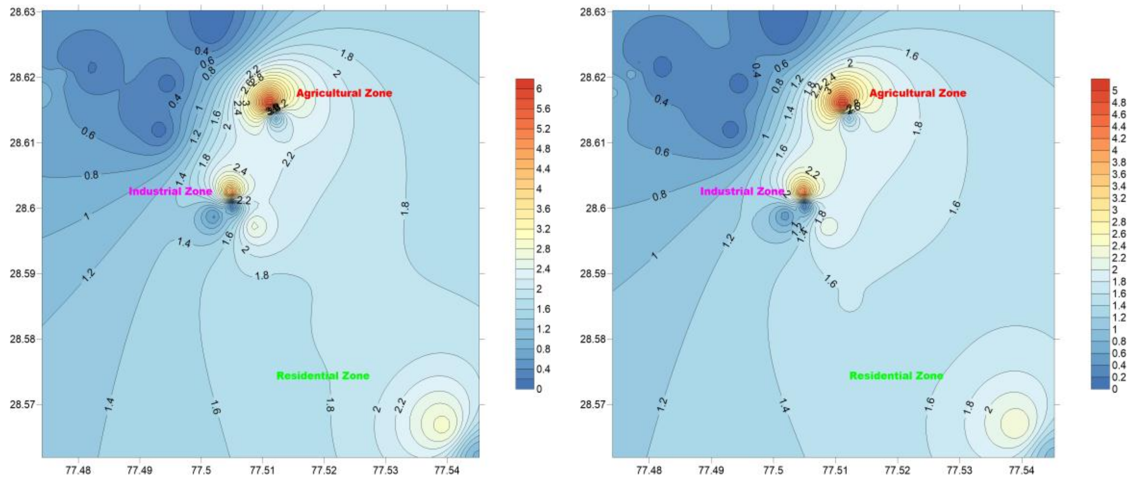
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.2.10 Spatial distribution of Cadmium in Groundwater samples during study period (2016-2018)

5.2.2.3 Chromium

Chromium is an essential vital element required for healthy human body (Ogoyi et al., 2011). In minute quantity, Cr (III) is appeared to be a necessary part of diet of healthy person. It prevent human body from metabolic disorders and diabetes. Chromium (III) is required for the metabolism of glucose and lipids. Chromium is present in the effluent of different industries such as tanning and leather manufacturing, paints and pigments, electroplating, textile, dying, fungicides, ceramics, photography and metal processing etc. Chromium is present in aqueous media mainly in two oxidation states Cr (III) and Cr (VI). Trivalent Chromium (in small quantity) is required for biological metabolism but hexavalent Chromium is toxic and carcinogenic to humans. Cr (VI) is 500 times more toxic than Cr (III) (Belay, 2010). In solutions Cr (VI) can be present in different forms (like chromate $Cr_2O_4^{2-}$, hydrochromate $HCrO_4^-$ or dichromate $Cr_2O_7^{2-}$) depending upon the pH of the solution. The standard limit of chromium in drinking water prescribed by WHO & BIS is 50 µg/L. The prolonged consumption of chromium contaminated water causes body weakness, kidney and liver damage, ulcers on the skin and paralysis.

During study period, analytical results of chromium in all twenty-two groundwater samples are given in Table – 5.2.2.5 and 5.2.2.6.

In study area, chromium concentration of groundwater ranged from 5.189 µg/L to 40.02 µg/L with a mean of 13.868 µg/L. Minimum concentration of chromium was obtained from Duryai water quality station in post-monsoon sample of year 2017. Sample collected from Bisrakh water quality station in pre-monsoon sample of year 2017 showed maximum concentration of chromium. In year 2016, 2017 and 2018, chromium concentration ranged from 6.003 µg/L (in post-monsoon season, Bishnuli) to 37.52 µg/L (in pre-monsoon season, Dujana), 5.189 µg/L (in post-monsoon season, Duryai) to 40.02 µg/L (in pre-monsoon season, Bisrakh Road) and 6.311 µg/L (in post-monsoon season, Dhoom Manikpur) to 39.877 µg/L (in pre-monsoon season, Bisrakh Road) respectively.

Table – 5.2.2.5 Seasonal Variation in Chromium concentration (in µg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	10.414	8.941	8.918	5.73%	3.47%	5.95%
			Post-monsoon	9.817	8.631	8.387			
	S2	Duryai	Pre-monsoon	7.528	6.662	7.618	4.50%	22.11%	5.21%
			Post-monsoon	7.189	5.189	7.221			
	S3	Duryai	Pre-monsoon	9.326	9.24	10.443	0.10%	0.21%	0.14%
			Post-monsoon	9.317	9.221	10.428			
	S4	Talabpur	Pre-monsoon	9.154	8.978	8.8	1.55%	1.63%	1.23%
			Post-monsoon	9.012	8.832	8.692			
Industrial	S5	Bisrakh Road	Pre-monsoon	15.43	10.79	12.684	0.55%	0.80%	0.89%
			Post-monsoon	15.345	10.704	12.571			
	S6	Bisrakh Road	Pre-monsoon	14.573	14.57	18.551	0.80%	-1.74%	0.59%
			Post-monsoon	14.457	14.823	18.441			
	S7	Bisrakh Road	Pre-monsoon	35.12	40.02	39.877	0.38%	0.84%	0.17%
			Post-monsoon	34.985	39.685	39.811			
	S8	Bisrakh Road	Pre-monsoon	9.315	8.12	9.844	1.36%	1.51%	1.45%
			Post-monsoon	9.188	7.997	9.701			
	S9	Bisrakh Road	Pre-monsoon	8.532	6.5	8.527	1.34%	1.35%	0.69%
			Post-monsoon	8.418	6.412	8.468			
	S10	Khera Dharampura	Pre-monsoon	11.428	13.23	13.219	0.90%	0.94%	1.57%
			Post-monsoon	11.325	13.106	13.012			
	S11	Bishnuli	Pre-monsoon	6.154	7.45	7.622	2.45%	0.93%	1.63%
			Post-monsoon	6.003	7.381	7.498			
	S12	Achheja	Pre-monsoon	16.895	17.22	17.43	1.06%	0.37%	0.71%
			Post-monsoon	16.716	17.156	17.306			
	S13	Achheja	Pre-monsoon	8.971	9.09	9.131	1.73%	1.14%	1.40%
			Post-monsoon	8.816	8.986	9.003			
	S14	Dujana	Pre-monsoon	15.278	15.641	18.236	0.81%	0.96%	0.76%
			Post-monsoon	15.155	15.491	18.097			
	S15	Dujana	Pre-monsoon	8.823	9.43	9.542	1.35%	1.28%	1.34%
			Post-monsoon	8.704	9.309	9.414			
	S16	Dujana	Pre-monsoon	9.832	9.91	10.214	2.25%	0.98%	1.06%
			Post-monsoon	9.611	9.813	10.106			
	S17	Dujana	Pre-monsoon	37.52	38.26	38.971	0.54%	0.40%	0.38%
			Post-monsoon	37.318	38.108	38.821			
	S18	Badalpur	Pre-monsoon	31.755	31.82	32.314	0.39%	0.32%	3.52%
			Post-monsoon	31.631	31.719	31.177			
Residential	S19	Sadopur	Pre-monsoon	10.983	11.15	11.481	1.16%	0.34%	0.71%
			Post-monsoon	10.856	11.112	11.4			
	S20	Dairy Maccha	Pre-monsoon	9.31	10.01	10.317	0.41%	0.10%	1.06%
			Post-monsoon	9.272	10	10.208			
	S21	Dhoom Manikpur	Pre-monsoon	6.362	6.37	6.421	0.97%	1.44%	1.71%
			Post-monsoon	6.3	6.278	6.311			
	S22	Badhpura	Pre-monsoon	8.241	8.1	8.241	0.90%	1.14%	1.37%
			Post-monsoon	8.167	8.008	8.128			

Table – 5.2.2.6 Statistical Summary of Chromium (in µg/L) in Groundwater samples

Year	2016				2017				2018			
Season	Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon		Pre-monsoon		Post-monsoon	
Min.	6.154	Bishnuli	6.003	Bishnuli	6.37	Dhoom Manikpur	5.189	Duryai	6.421	Dhoom Manikpur	6.311	Dhoom Manikpur
Max.	37.52	Dujana	37.318	Dujana	40.02	Bisrakh Road	39.685	Bisrakh Road	39.877	Bisrakh Road	39.811	Bisrakh Road
Mean	13.679		13.527		13.705		13.544		14.473		14.282	
St. Dev.	9.094		9.094		9.869		9.887		9.854		9.788	

In agricultural zone of study area, chromium concentration varied from 5.189 to 10.443 µg/L with a mean of 8.665 µg/L. A wide variation was observed in chromium concentration in industrial zone (6.003 to 40.02 µg/L). Residential zone had chromium concentration from 6.278 to 11.481 µg/L. Minimum value of chromium was obtained from Dhoom Manikpur station and maximum from Sadopur station.

Percent change from pre-monsoon to post-monsoon season revealed decrease in chromium concentration after rainfall due to recharge of ground aquifers. Only one sample collected from Bisrakh Road station in year 2017, has slight increase in chromium content after rainfall. The reason behind the increase in chromium content was presence of iron and steel industries near the source of sample.

Distribution plot of Chromium concentration in groundwater samples throughout the study period (2016, 2017 & 2018) at all twenty-two water quality stations is presented in Fig. 5.2.2.11, 5.2.2.12 & 5.2.2.13, respectively. A gradual increase was observed in mean concentration of chromium from 2016 to 2018 (13.603 < 13.624 < 14.377 µg/L) through Box and Whisker plot (Fig. 5.2.2.14). Spatial distribution map of chromium content of groundwater in study area also showed relative level of chromium at studied water quality stations (Fig. 5.2.2.15).

All the analysed samples have chromium concentration below the standard limit of BIS and WHO. Presence of high amount of chromium in the vicinity of tannery unit was reported by several authors (Brindha, 2012; Oruku, 2014; Azom, 2012 & Ramesh, 2014).

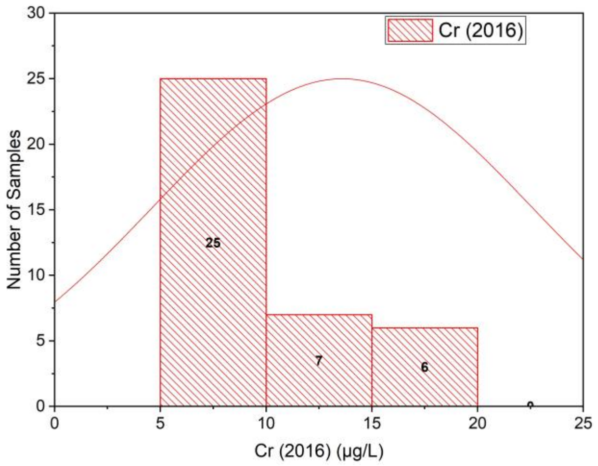


Fig. 5.2.2.11 Empirical probability distribution of Chromium concentration in Groundwater samples (in year 2016)

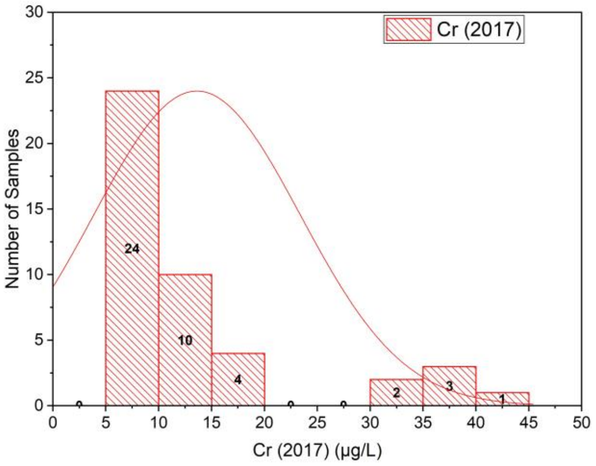


Fig. 5.2.2.12 Empirical probability distribution of Chromium concentration in Groundwater samples (in year 2017)

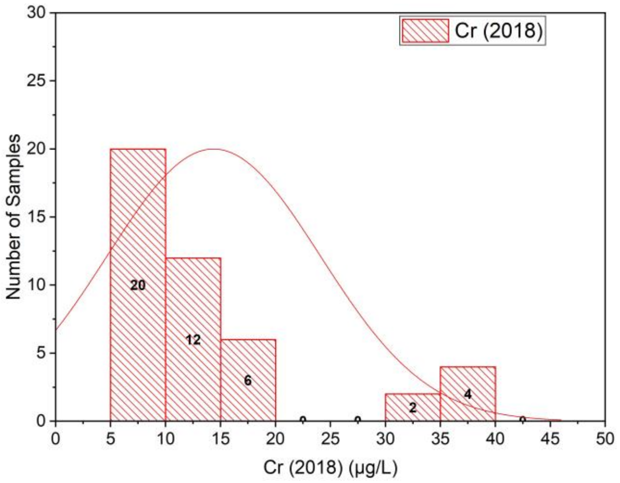


Fig. 5.2.2.13 Empirical probability distribution of Chromium concentration in Groundwater samples (in year 2018)

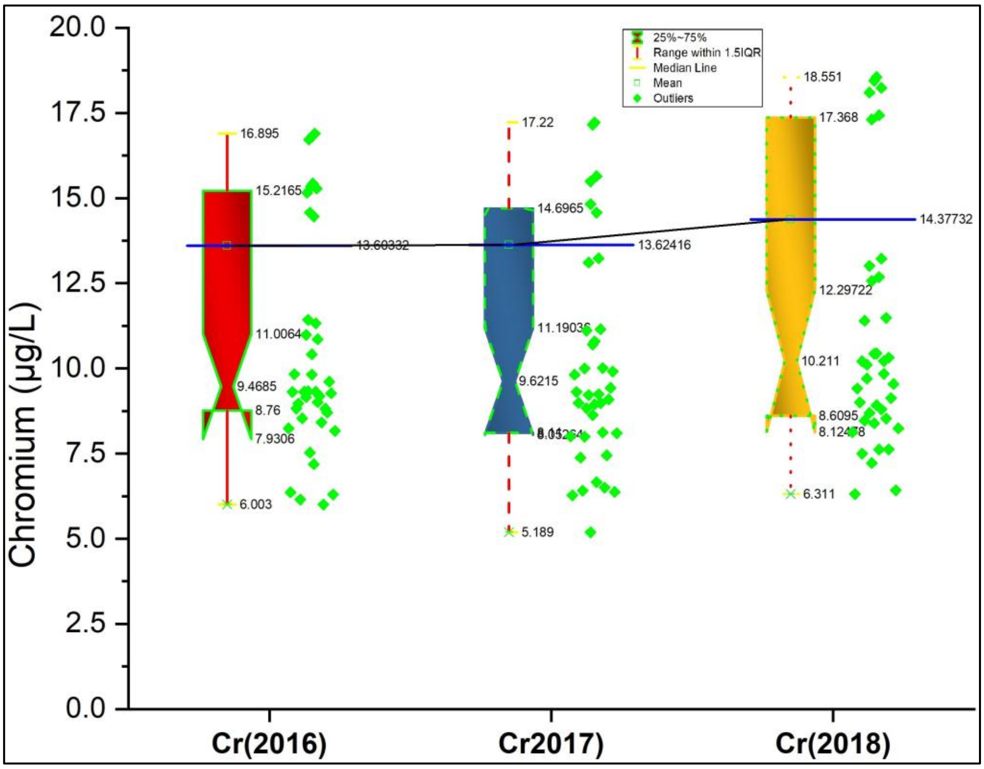
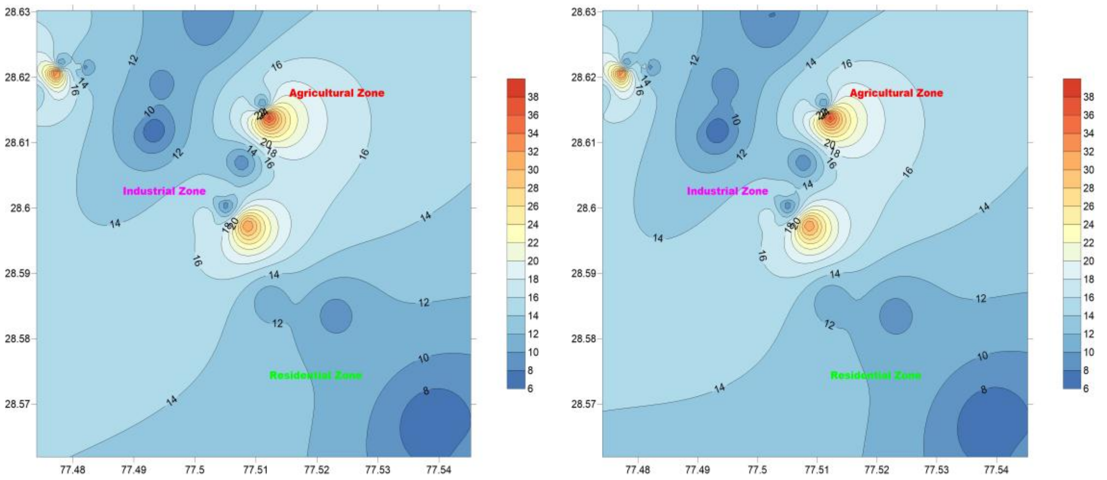
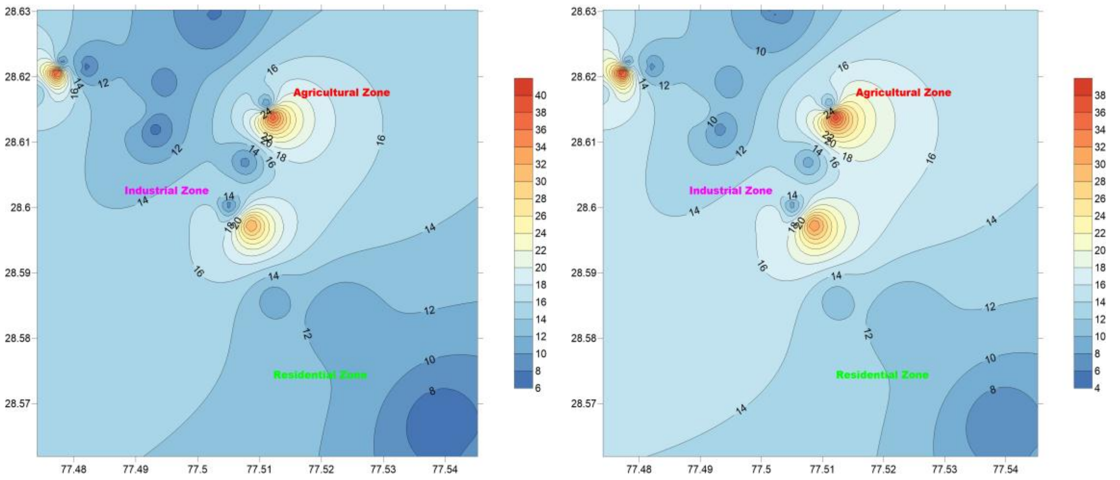


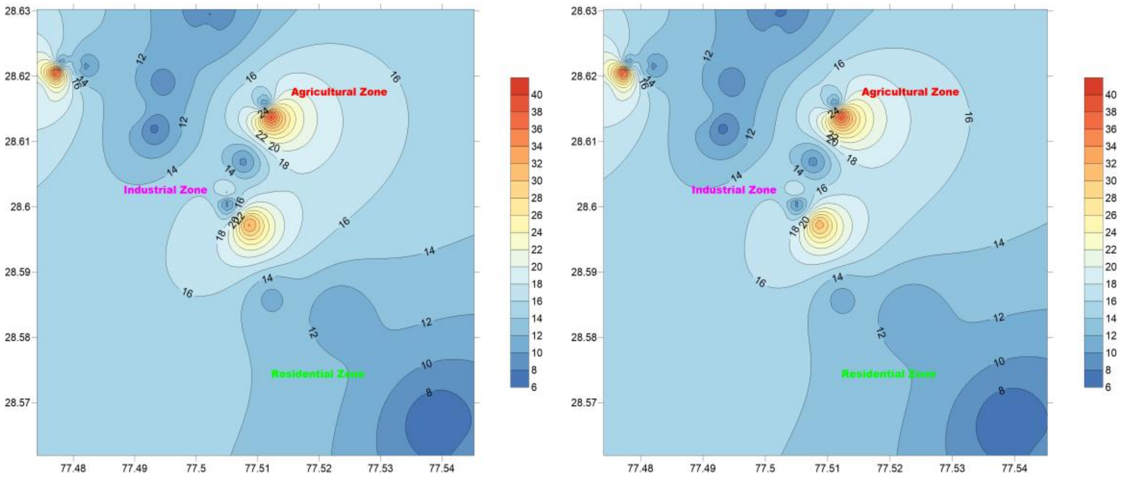
Fig. 5.2.2.14 Box and Whisker plot of Chromium concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.2.15 Spatial distribution of Chromium in Groundwater samples during study period (2016-2018)

5.2.2.4 Copper

The occurrence of copper in different sphere of earth is wide. Its concentration in earth crust is found 68 ppm, in soil 9 to 33 ppm, in rivers 4 to 12 µg/L and in groundwater < 0.1 mg/L (APHA, 2012). Copper metal is widely used for commercial purpose (paints, ceramics, pesticides, and in the chemical industry). In nature, it is present in three states- elemental state, ionic states; cuprous and cupric. The anthropogenic sources of copper in aquifers are copper mining and smelting, corrosion of copper alloys in pipe fittings, steel industry, power plants, agricultural activities and sewer sludge. It is a necessary metal for the proper growth of an organism and iron metabolism. The recommended value of copper intake by a healthy person is 1.53 mg/day (NRC, 1989). Higher intake of copper causes toxicity in humans and young children are more susceptible to copper toxicity. High concentration of copper in human body results into damage of liver and kidney. Prolonged exposure to copper fumes may cause metal fume fever with atrophic changes in mucous membrane of nasal cavity. The Swedish standard for copper content in drinking water is 2 mg/L which can prevent acute toxicity symptoms of copper (Livsmedelsverket fo¨ rfattningssamling, 2005).

During study period, analytical results of copper in all twenty-two groundwater samples are given in Table – 5.2.2.7 and 5.2.2.8.

BIS: 10500 (2012) sets the acceptable limit of copper 50 µg/L in drinking water and 1500 µg/L as a permissible value. WHO gives a health based guideline value of 2000 µg/L for copper for drinking water. Copper content of water higher than 500 µg/L gives unpleasant taste and colour to it. During study period, the mean value of copper in analysed samples was 4.046 ± 1.830 µg/L which was far below the standard values of copper given by BIS and WHO. Minimum value of copper 1.005 µg/L was obtained from Bisrakh Road water quality station in post-monsoon sample of year 2017 and maximum value of 8.719 µg/L was found at Talabpur station in pre-monsoon sample of year 2018.

Table – 5.2.2.7 Seasonal Variation in Copper concentration (in µg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	6.813	4.218	5.775	7.13%	9.36%	-0.80%
			Post-monsoon	6.327	3.823	5.821			
	S2	Duryai	Pre-monsoon	3.872	2.88	2.514	0.96%	0.31%	-0.44%
			Post-monsoon	3.835	2.871	2.525			
	S3	Duryai	Pre-monsoon	2.745	1.993	2.831	-0.26%	0.15%	0.39%
			Post-monsoon	2.752	1.99	2.82			
	S4	Talabpur	Pre-monsoon	4.361	3.602	8.719	-0.71%	-0.72%	0.10%
			Post-monsoon	4.392	3.628	8.71			
Industrial	S5	Bisrakh Road	Pre-monsoon	6.331	2.17	2.964	-3.30%	-2.21%	-0.24%
			Post-monsoon	6.54	2.218	2.971			
	S6	Bisrakh Road	Pre-monsoon	6.716	6.518	7.436	-0.06%	0.05%	-2.84%
			Post-monsoon	6.72	6.515	7.647			
	S7	Bisrakh Road	Pre-monsoon	3.156	2.07	2.897	4.82%	-2.42%	0.41%
			Post-monsoon	3.004	2.12	2.885			
	S8	Bisrakh Road	Pre-monsoon	6.13	4.86	4.982	2.02%	2.39%	2.67%
			Post-monsoon	6.006	4.744	4.849			
	S9	Bisrakh Road	Pre-monsoon	2.413	1.16	2.225	3.11%	13.36%	1.80%
			Post-monsoon	2.338	1.005	2.185			
	S10	Khera Dharampura	Pre-monsoon	5.156	4.61	4.971	0.74%	0.59%	0.99%
			Post-monsoon	5.118	4.583	4.922			
	S11	Bishnuli	Pre-monsoon	8.412	8.203	8.319	-0.45%	-0.27%	0.11%
			Post-monsoon	8.45	8.225	8.31			
	S12	Achheja	Pre-monsoon	4.382	4.42	4.442	-0.14%	-0.25%	-0.07%
			Post-monsoon	4.388	4.431	4.445			
	S13	Achheja	Pre-monsoon	3.716	2.98	3.418	-0.13%	-0.50%	-0.67%
			Post-monsoon	3.721	2.995	3.441			
	S14	Dujana	Pre-monsoon	4.551	4.96	4.872	-0.29%	-0.50%	-0.25%
			Post-monsoon	4.564	4.985	4.884			
	S15	Dujana	Pre-monsoon	4.138	4.14	4.562	0.19%	0.46%	0.28%
			Post-monsoon	4.13	4.121	4.549			
	S16	Dujana	Pre-monsoon	4.312	4.75	4.798	0.42%	0.25%	0.35%
			Post-monsoon	4.294	4.738	4.781			
	S17	Dujana	Pre-monsoon	1.935	1.73	1.831	0.83%	-0.69%	-0.93%
			Post-monsoon	1.919	1.742	1.848			
	S18	Badalpur	Pre-monsoon	2.63	2.9	3.512	-0.08%	-0.17%	-1.00%
			Post-monsoon	2.632	2.905	3.547			
Residential	S19	Sadopur	Pre-monsoon	1.665	1.88	1.895	0.42%	5.32%	0.21%
			Post-monsoon	1.658	1.78	1.891			
	S20	Dairy Maccha	Pre-monsoon	4.641	4.79	6.187	0.28%	1.04%	0.11%
			Post-monsoon	4.628	4.74	6.18			
	S21	Dhoom Manikpur	Pre-monsoon	2.831	2.92	2.954	-0.32%	-0.51%	-0.03%
			Post-monsoon	2.84	2.935	2.955			
	S22	Badhpura	Pre-monsoon	2.271	2.22	2.427	-0.13%	-0.23%	-0.12%
			Post-monsoon	2.274	2.225	2.43			

Table – 5.2.2.8 Statistical Summary of Copper (in µg/L) in Groundwater samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	1.665	Sadopur	1.658	Sadopur	1.16	Bisrakh Road	1.005	Bisrakh Road	1.831	Dujana	1.848	Dujana
Max.	8.412	Bishnuli	8.45	Bishnuli	8.203	Bishnuli	8.225	Bishnuli	8.719	Talabpur	8.71	Talabpur
Mean	4.235		4.206		3.635		3.605		4.297		4.300	
St. Dev.	1.784		1.772		1.709		1.713		2.010		2.023	

In three consecutive years of study (2016 to 2018), the mean value of copper was 4.221, 3.620 and 4.298 µg/L respectively. Copper concentration ranged from 1.658 µg/L to 8.45 µg/L (in year 2016), 1.005 µg/L to 8.225 µg/L (in year 2017) and 1.831 µg/L to 8.719 µg/L (in year 2018). In year 2016 & 2017, maximum value was obtained from Bishnuli station while in year 2018, Talabpur station has maximum value of copper.

In agricultural zone of study area, copper content varied from 1.99 µg/L (at Duryai station in year 2017) to 8.719 µg/L (at Talabpur station in year 2018) with a mean value of 4.159 µg/L. Industrial zone of study area showed copper content from 1.005 µg/L (at Bisrakh Road station in year 2017) to 8.45 µg/L (at Bishnuli station in year 2016) with a mean of 4.299 µg/L. In residential zone, a minimum value of 1.658 µg/L was obtained from Sadopur station in year 2016 and a maximum value of 6.187 µg/L at Dairy Maccha station in year 2018.

Percent change in copper concentration from pre-monsoon to post-season revealed that at few stations copper content of groundwater decreased. Majority of samples showed increase in copper content after rainfall due to dissolution of metal.

The empirical probability distribution plot of copper concentration in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.2.16, 5.2.2.17 and 5.2.2.18 respectively. Box and Whisker plot was also drawn to know the distributional characteristics of copper concentration of groundwater during study period (Fig. 5.2.2.19). Contour map of copper content of all analysed groundwater samples during study period showed relatively higher concentration at industrial and agricultural region (Fig 5.2.2.20).

Copper is a major component of metallo-enzymes in living beings. It is also required for synthesis of haemoglobin and as a catalyst during various matabolic reactons (Dural et al., 2007). During whole study period, copper content of groundwater remained below the guideline value of BIS and WHO. Ibraheem & Khan, (2017) stated a mean concentration of 111 µg/L in groundwater of Perambalur district of Tamilnadu. Similar types of results were obtained by many researchers (Brindha et al., 2010; Rajappa et al., 2010; Adelekan & Abegunde, 2011; Anake et al., 2014; Ćurković et al., 2016; Nwankwoala et al., 2016).

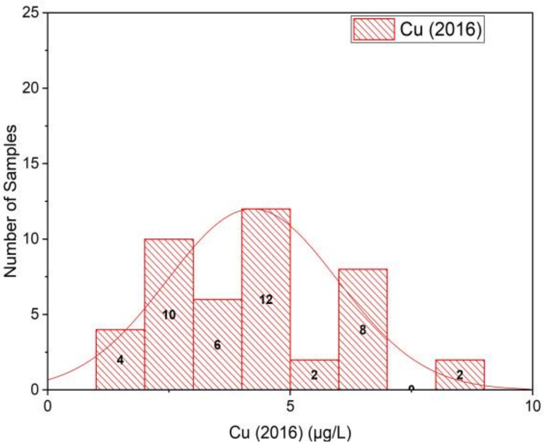


Fig. 5.2.2.16 Empirical probability distribution of Copper concentration in Groundwater samples (in year 2016)

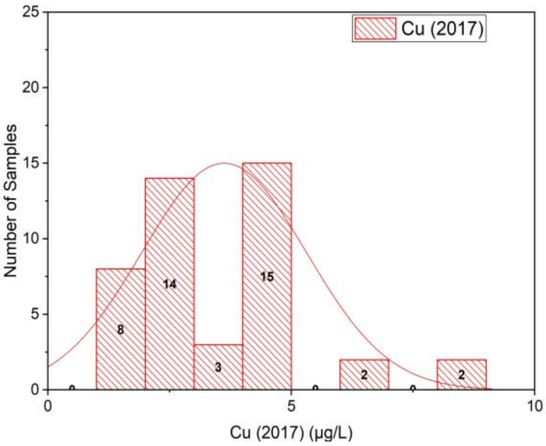


Fig. 5.2.2.17 Empirical probability distribution of Copper concentration in Groundwater samples (in year 2017)

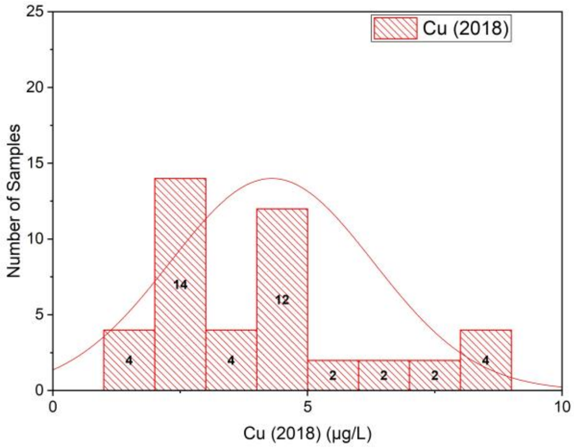


Fig. 5.2.2.18 Empirical probability distribution of Copper concentration in Groundwater samples (in year 2018)

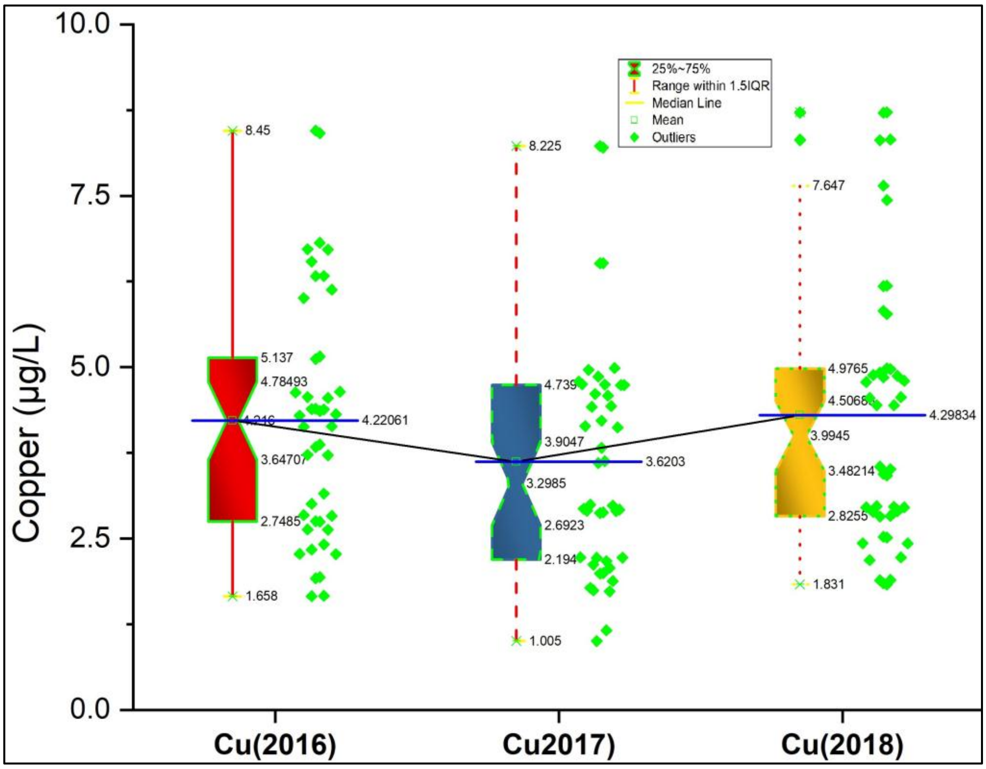
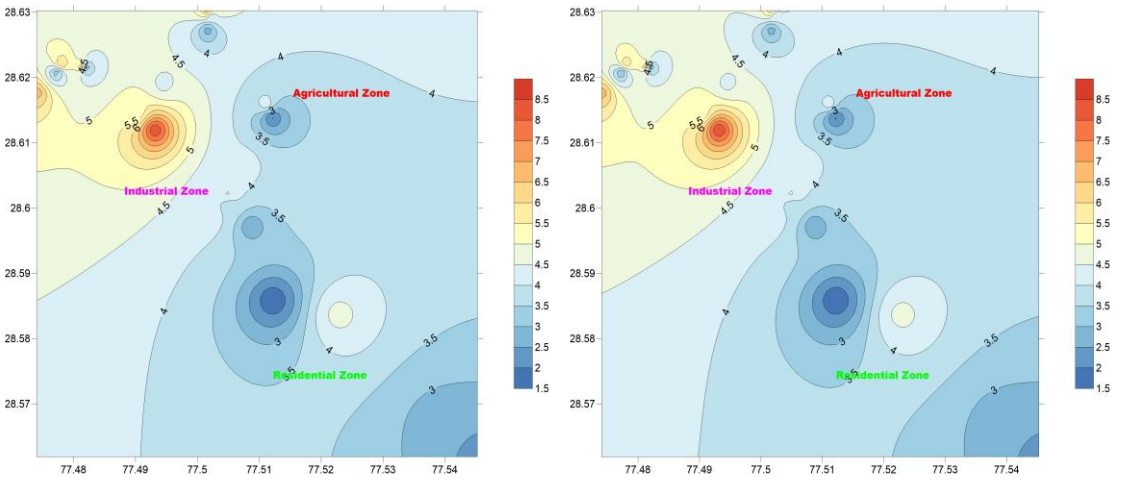
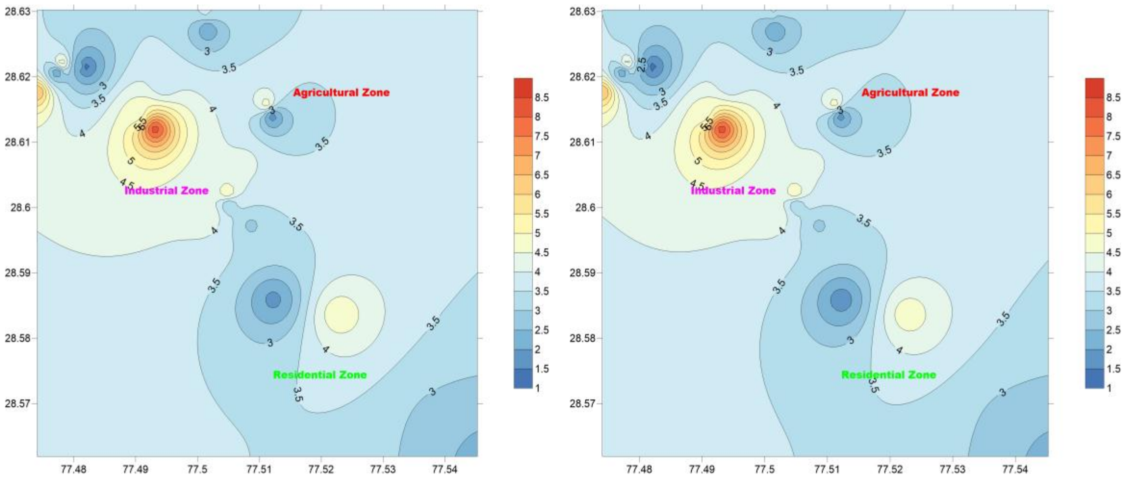


Fig. 5.2.2.19 Box and Whisker plot of Copper concentration in Groundwater samples during study period (2016-2018)



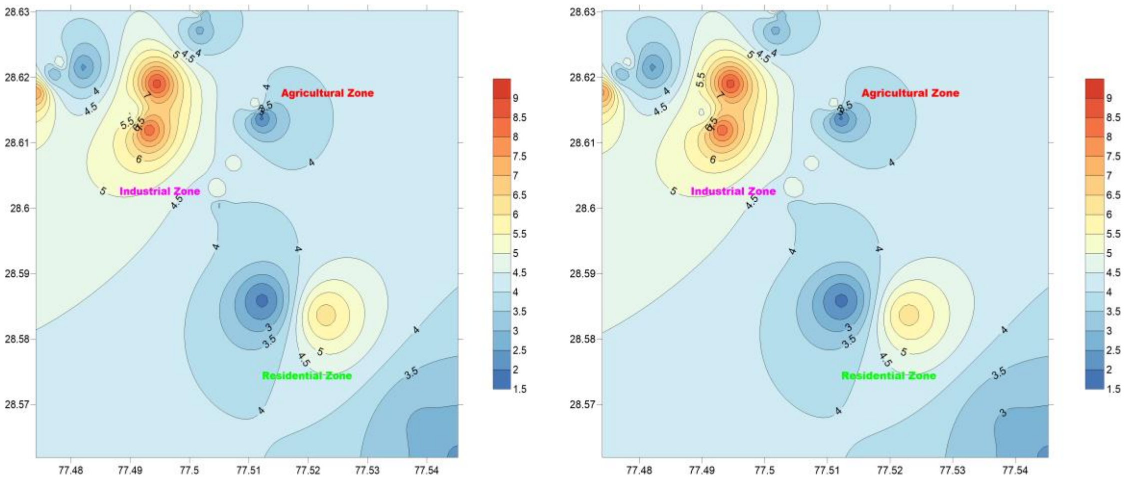
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.2.20 Spatial distribution of Copper in Groundwater samples during study period (2016-2018)

5.2.2.5 Nickel

Presence of nickel, in trace amount, is essential for animals, plants and micro-organisms. Its deficiency or toxicity can happen when adequate amount of nickel is not ingested (Cempel & Nikel, 2006). It is twenty-fourth most abundant element on earth. In earth's crust, natural concentration of nickel is 1.2 mg/L, in soils 2.5 mg/L and in groundwater 0.1 mg/L. The major ores of nickel are pyrrhotite, garnierite, nickelite (NiAs), millerite (NiS) and pentlandite (Ni, FeS). Nickel is used in many commercial products like alloys (stainless steel), magnets, protective coatings, catalyst and batteries. Nickel content of environment increases due to various human activities like mining works, steel manufacturing units, electroplating, emission of smelters, burning of fossil fuels, sewage, and agricultural runoff. Nickel salts are highly soluble in water and hence easily entered into aquatic environment. Nickel is ubiquitous in nature and plays a crucial role in functioning of many organisms but its high concentrations may be toxic to living organisms. Intake of excessive amount of nickel causes skin allergy. Nickel is reported as one of the most common cause of allergic contact dermatitis (Clarkson, 1988). Very high concentration of nickel is carcinogenic to human and cause changes in muscle, brain, lungs, liver, and kidney (Ramteke & Moghe, 1986).

During study period, analytical results of nickel in all twenty-two groundwater samples are given in Table – 5.2.2.9 and 5.2.2.10.

The nickel content in analysed samples varied from 0.377 to 14.56 µg/L with a mean value of 6.202 ± 3.946 µg/L. Its minimum concentration was obtained from Achheja water quality station and maximum from Badalpur station. In year 2016 it was found minimum (0.418 µg/L) at Achheja water quality station in post-monsoon season and maximum (14.419 µg/L) at Bisrakh Road water quality station in pre-monsoon season with a mean of 6.145 µg/L. During year 2017 & 2018 nickel content of groundwater ranged from 0.377 to 14.26 µg/L & 0.442 to 14.56 µg/L respectively. In both the year maximum concentration of nickel was obtained from Badalpur water quality station.

Table – 5.2.2.9 Seasonal Variation in Nickel concentration (in µg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	3.16	2.24	2.532	4.53%	3.08%	16.35%
			Post-monsoon	3.017	2.171	2.118			
	S2	Duryai	Pre-monsoon	2.751	1.73	2.615	0.58%	1.85%	0.50%
			Post-monsoon	2.735	1.698	2.602			
	S3	Duryai	Pre-monsoon	3.819	4.78	4.665	0.47%	5.48%	1.18%
			Post-monsoon	3.801	4.518	4.61			
	S4	Talabpur	Pre-monsoon	7.233	6.33	7.551	1.13%	1.09%	1.70%
			Post-monsoon	7.151	6.261	7.423			
Industrial	S5	Bisrakh Road	Pre-monsoon	14.419	12.12	12.975	1.37%	0.10%	4.31%
			Post-monsoon	14.221	12.108	12.416			
	S6	Bisrakh Road	Pre-monsoon	13.378	13.556	10.388	1.94%	1.71%	2.66%
			Post-monsoon	13.119	13.324	10.112			
	S7	Bisrakh Road	Pre-monsoon	3.553	8.95	7.421	5.88%	1.54%	1.55%
			Post-monsoon	3.344	8.812	7.306			
	S8	Bisrakh Road	Pre-monsoon	7.426	7.55	7.853	1.45%	1.62%	1.81%
			Post-monsoon	7.318	7.428	7.711			
	S9	Bisrakh Road	Pre-monsoon	10.416	9.85	9.744	1.90%	2.11%	1.40%
			Post-monsoon	10.218	9.642	9.608			
	S10	Khera Dharampura	Pre-monsoon	9.862	9.78	10.124	0.72%	1.00%	0.22%
			Post-monsoon	9.791	9.682	10.102			
	S11	Bishnuli	Pre-monsoon	5.187	4.621	4.961	6.11%	6.41%	10.68%
			Post-monsoon	4.87	4.325	4.431			
	S12	Achheja	Pre-monsoon	3.439	3.56	3.772	0.32%	0.06%	0.32%
			Post-monsoon	3.428	3.558	3.76			
	S13	Achheja	Pre-monsoon	0.429	0.39	0.452	2.56%	3.33%	2.21%
			Post-monsoon	0.418	0.377	0.442			
	S14	Dujana	Pre-monsoon	7.186	6.9	7.217	1.24%	1.29%	1.57%
			Post-monsoon	7.097	6.811	7.104			
	S15	Dujana	Pre-monsoon	4.341	4.32	4.727	2.88%	2.38%	2.39%
			Post-monsoon	4.216	4.217	4.614			
	S16	Dujana	Pre-monsoon	0.921	0.88	0.944	0.54%	1.36%	1.80%
			Post-monsoon	0.916	0.868	0.927			
	S17	Dujana	Pre-monsoon	7.425	7.89	7.916	0.11%	0.24%	0.16%
			Post-monsoon	7.417	7.871	7.903			
	S18	Badalpur	Pre-monsoon	14.112	14.26	14.56	0.03%	0.11%	0.11%
			Post-monsoon	14.108	14.245	14.544			
Residential	S19	Sadopur	Pre-monsoon	4.776	5.23	5.421	0.27%	0.15%	0.15%
			Post-monsoon	4.763	5.222	5.413			
	S20	Dairy Maccha	Pre-monsoon	8.442	8.65	8.689	0.08%	0.14%	0.20%
			Post-monsoon	8.435	8.638	8.672			
	S21	Dhoom Manikpur	Pre-monsoon	1.431	1.45	1.573	0.21%	0.48%	0.32%
			Post-monsoon	1.428	1.443	1.568			
	S22	Badhpura	Pre-monsoon	2.423	2.56	2.722	0.17%	0.27%	0.73%
			Post-monsoon	2.419	2.553	2.702			

Table – 5.2.2.10 Statistical Summary of Nickel (in µg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.429	Achheja	0.418	Achheja	0.39	Achheja	0.377	Achheja	0.452	Achheja	0.442	Achheja
Max.	14.419	Bisrakh Road	14.221	Bisrakh Road	14.26	Badalpur	14.245	Badalpur	14.56	Badalpur	14.544	Badalpur
Mean	6.188		6.101		6.254		6.171		6.310		6.186	
St. Dev.	4.192		4.157		4.073		4.052		3.844		3.806	

In agricultural zone of study area, nickel concentration was found between 1.698 µg/L (at Duryai station in 2017) and 7.551 µg/L (at Talabpur station in 2018). In industrial zone of study area its concentration in groundwater varied from 0.377 µg/L (at Achheja in 2017) to 14.56 µg/L (at Badalpur in 2018). Residential zone showed nickel concentration from 1.428 µg/L (at Dhoom Manikpur in 2016) to 8.689 µg/L (at Dairy Maccha in 2018). In agricultural, industrial and residential zone, mean value of nickel content was 4.063 µg/L, 7.316 µg/L and 4.443 µg/L respectively.

Percent change of nickel concentration from pre-monsoon to post-monsoon samples showed net dilution of groundwater. The empirical probability distribution plot with respect to nickel concentration at all the twenty-two water quality stations of the study area during study period (2016, 2017 & 2018) is shown in Fig. 5.2.2.21, 5.2.2.22 and 5.2.2.23 respectively. A gradual increase in mean value of nickel was observed from 2017 to 2018 (6.145 < 6.213 < 6.248). Box and Whisker plot of nickel content in analysed samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.2.2.24. GIS map of nickel content in groundwater of study area showed that higher nickel content in groundwater of Bisrakh Road & Badalpur water quality station (Fig. 5.2.2.25).

BIS: 10500 (2012) gives an acceptable limit of 20 µg/L of nickel in drinking water and there is no relaxation in this limit. WHO (2017) sets a health based guideline value of 70 µg/L of nickel in drinking water. On the basis of analytical results, it is concluded that all the collected samples were within the standard limit of nickel given by BIS and WHO. Majolagbe et al., (2017) reported 10 to 80 µg/L of nickel in groundwater of Lagos, Nigeria. Nickel content of groundwater was studied by several researchers (Adelekan & Abegunde, 2011; Ayedun et al., 2012; Sekhon & Singh, 2013; Nwankwoala et al., 2016).

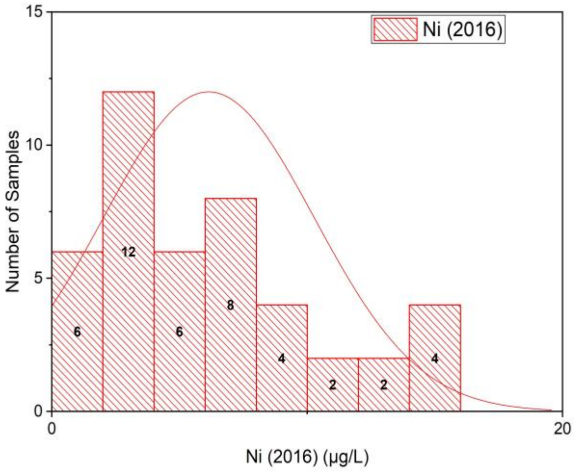


Fig. 5.2.2.21 Empirical probability distribution of Nickel concentration in Groundwater samples (in year 2016)

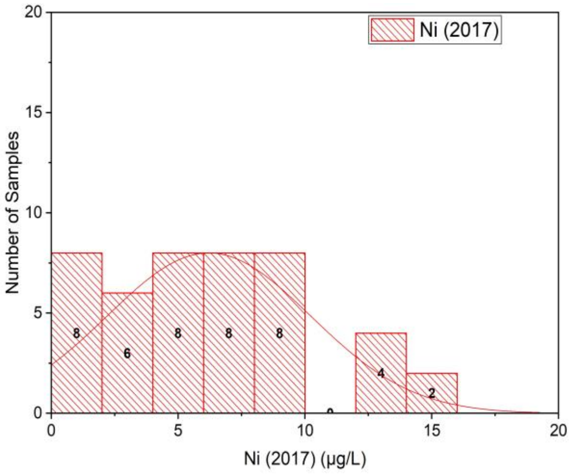


Fig. 5.2.2.22 Empirical probability distribution of Nickel concentration in Groundwater samples (in year 2017)

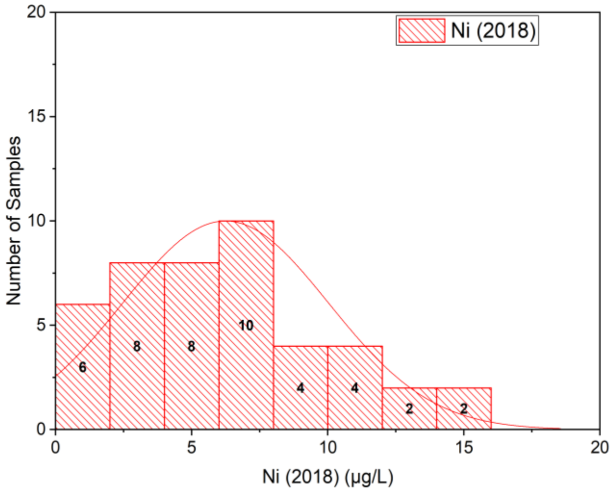


Fig. 5.2.2.23 Empirical probability distribution of Nickel concentration in Groundwater samples (in year 2018)

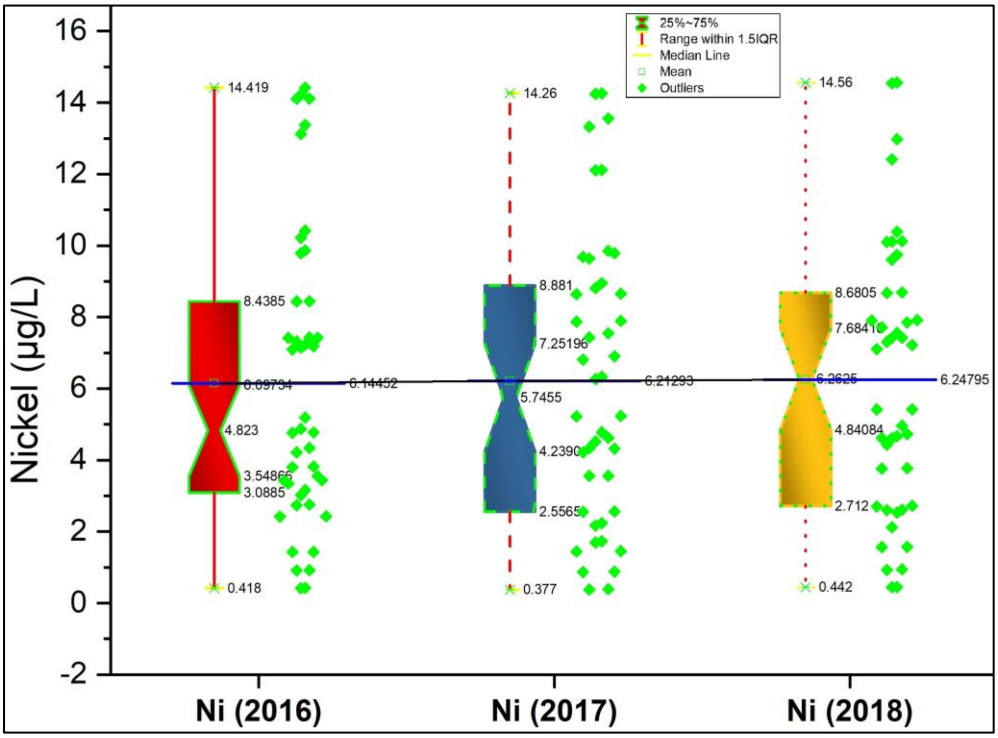
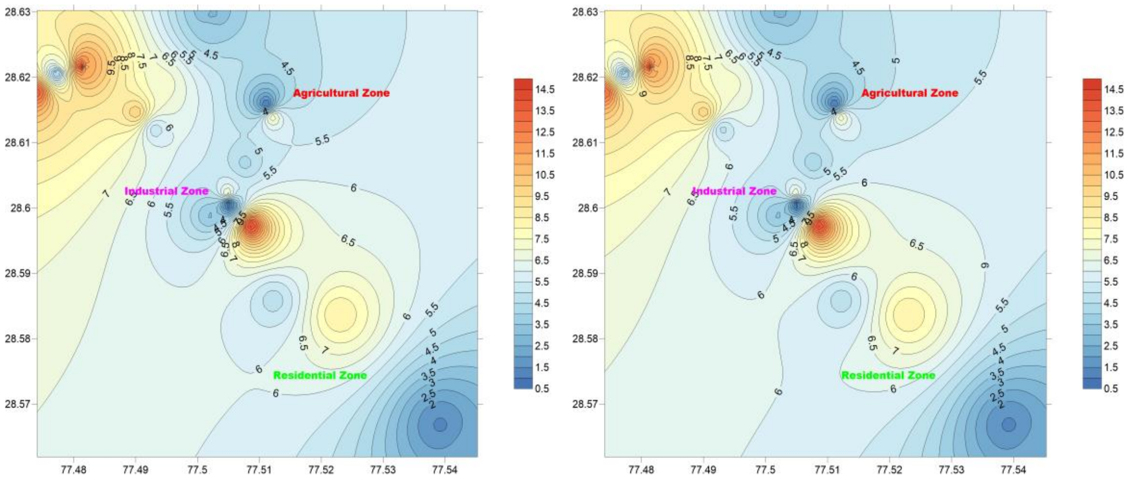
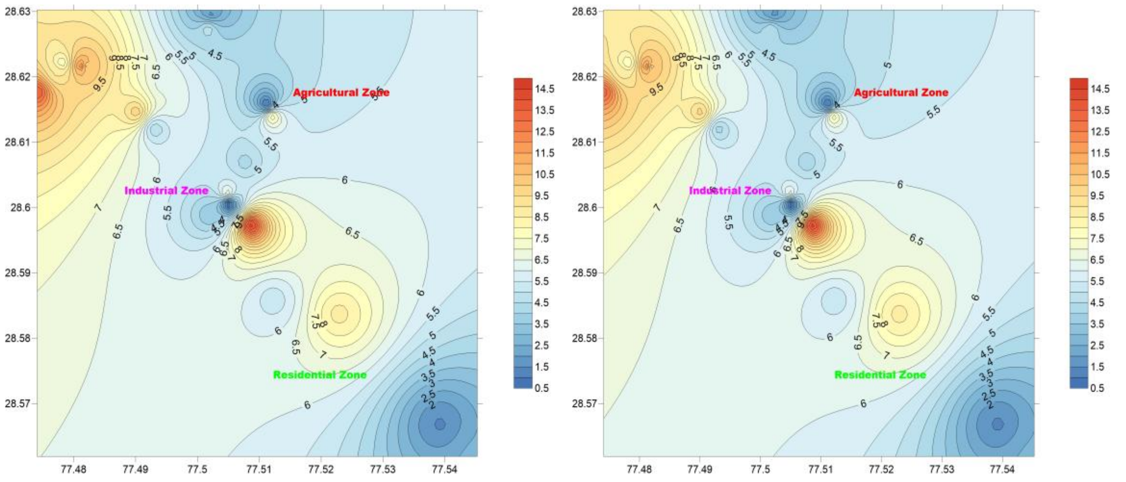


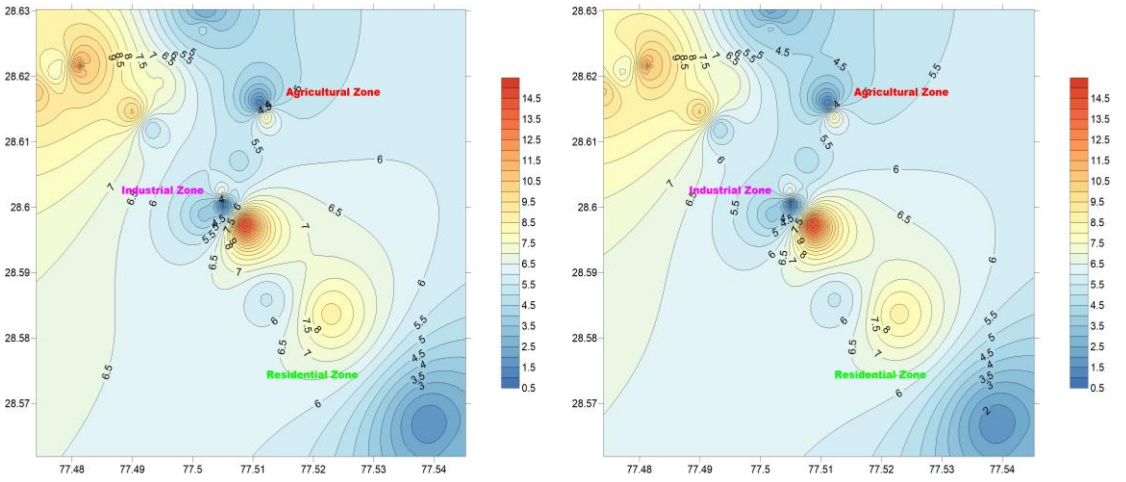
Fig. 5.2.2.24 Box and Whisker plot of Nickel concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.2.25 Spatial distribution of Nickel in Groundwater samples during study period (2016-2018)

5.2.2.6 Lead

Lead is bluish-grey naturally occurring metal having low melting point. It is found in nature in combined form. It is the most widespread toxic metal found in environment. Lead is present in environment in small quantity but its concentration can be increased due to natural or anthropogenic sources. Lead is used in the manufacturing of batteries, plastics, china, ceramic glass and paint products. Lead in seldom present in natural drinking water but it can enters due to corrosion and wearing away of lead containing materials in water distribution system. Lead poisoning results into headache, abdominal pain, numbness, muscular weakness, kidney disorders and chronic impairment to the central nervous system and peripheral nervous system (Ogwuegbu & Muhanga, 2005). Young or unborn children are more vulnerable to lead toxicity as lead is easily absorbed in tissues of growing bodies. Lead affects the brain of children and resulted into poor attention span, poor intelligence quotient and noticeable learning difficulty (Udedi, 2003).

During study period, analytical results of lead in all twenty-two groundwater samples are given in Table – 5.2.2.11 and 5.2.2.12.

The content of lead extended from 1.403 to 6.265 µg/L with a mean value of 3.264 ± 0.966 µg/L, in the whole study period. Minimum value of 1.403 µg/L was recorded from Sadopur water quality station in post-monsoon sample of year 2016 and maximum value of 6.265 µg/L was recorded from Khera Dharampura water quality station in pre-monsoon sample of year 2016.

During 2016 the variation in lead in groundwater was from 1.403 to 6.265 µg/L while, in 2017 it ranged from a minimum of 1.698 µg/L to a maximum of 4.57 µg/L. It was observed that values varied from 1.891 to 5.823 µg/L during 2018.

Table - 5.2.2.11 Seasonal Variation in Lead concentration (in µg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	3.248	2.69	3.916	14.04%	14.09%	12.59%
			Post-monsoon	2.792	2.311	3.423			
	S2	Duryai	Pre-monsoon	3.55	2.683	2.698	0.34%	0.41%	0.37%
			Post-monsoon	3.538	2.672	2.688			
	S3	Duryai	Pre-monsoon	3.541	3.35	3.751	0.40%	0.27%	2.75%
			Post-monsoon	3.527	3.341	3.648			
	S4	Talabpur	Pre-monsoon	3.426	3.33	2.827	1.11%	3.33%	4.10%
			Post-monsoon	3.388	3.219	2.711			
Industrial	S5	Bisrakh Road	Pre-monsoon	4.416	2.23	2.186	6.75%	9.78%	8.42%
			Post-monsoon	4.118	2.012	2.002			
	S6	Bisrakh Road	Pre-monsoon	2.118	1.97	2.223	6.19%	4.01%	4.81%
			Post-monsoon	1.987	1.891	2.116			
	S7	Bisrakh Road	Pre-monsoon	5.361	4.067	5.269	4.01%	2.09%	1.61%
			Post-monsoon	5.146	3.982	5.184			
	S8	Bisrakh Road	Pre-monsoon	3.615	3.36	3.408	0.55%	4.43%	1.56%
			Post-monsoon	3.595	3.211	3.355			
	S9	Bisrakh Road	Pre-monsoon	3.332	2.36	2.445	2.28%	4.75%	5.48%
			Post-monsoon	3.256	2.248	2.311			
	S10	Khera Dharampura	Pre-monsoon	6.265	3.76	3.842	1.42%	3.54%	2.81%
			Post-monsoon	6.176	3.627	3.734			
	S11	Bishnuli	Pre-monsoon	5.618	4.57	5.823	3.65%	5.84%	3.06%
			Post-monsoon	5.413	4.303	5.645			
	S12	Achheja	Pre-monsoon	2.952	3.02	3.11	1.66%	0.53%	0.42%
			Post-monsoon	2.903	3.004	3.097			
	S13	Achheja	Pre-monsoon	2.413	2.5	2.532	0.66%	0.52%	1.07%
			Post-monsoon	2.397	2.487	2.505			
	S14	Dujana	Pre-monsoon	3.371	3.482	3.512	0.50%	0.49%	0.48%
			Post-monsoon	3.354	3.465	3.495			
	S15	Dujana	Pre-monsoon	3.923	3.94	4.12	0.31%	0.46%	0.56%
			Post-monsoon	3.911	3.922	4.097			
	S16	Dujana	Pre-monsoon	2.451	2.99	3.135	0.53%	0.17%	0.61%
			Post-monsoon	2.438	2.985	3.116			
	S17	Dujana	Pre-monsoon	3.776	3.8	3.977	0.32%	0.50%	0.40%
			Post-monsoon	3.764	3.781	3.961			
	S18	Badalpur	Pre-monsoon	3.525	3.78	3.786	0.26%	0.48%	0.40%
			Post-monsoon	3.516	3.762	3.771			
Residential	S19	Sadopur	Pre-monsoon	1.417	1.705	1.902	0.99%	0.41%	0.58%
			Post-monsoon	1.403	1.698	1.891			
	S20	Dairy Maccha	Pre-monsoon	2.218	2.23	2.416	0.72%	0.54%	0.66%
			Post-monsoon	2.202	2.218	2.4			
	S21	Dhoom Manikpur	Pre-monsoon	3.451	3.66	3.834	0.26%	0.22%	0.16%
			Post-monsoon	3.442	3.652	3.828			
	S22	Badhpura	Pre-monsoon	2.428	2.78	2.624	0.12%	0.32%	0.23%
			Post-monsoon	2.425	2.771	2.618			

Table – 5.2.2.12 Statistical Summary of Lead (in µg/L) in Groundwater samples

Year	2016				2017				2018			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	1.417	Sadopur	1.403	Sadopur	1.705	Sadopur	1.698	Sadopur	1.902	Sadopur	1.891	Sadopur
Max.	6.265	Khera Dharampura	6.176	Khera Dharampura	4.57	Bishnuli	4.303	Bishnuli	5.823	Bishnuli	5.654	Bishnuli
Mean	3.473		3.395		3.103		3.026		3.333		3.254	
St. Dev.	1.164		1.129		0.754		0.753		0.985		0.968	

In agricultural zone of study area, lead content ranged from 2.311 to 3.916 µg/L with a mean value of 3.178 µg/L. In industrial zone a minimum value of 1.891 µg/L (at Bisrakh Road water quality station in year 2017) and a maximum value of 6.265 µg/L (at Khera Dharampura water quality station in year 2016) of lead was observed. In residential zone, Sadopur water quality station in year 2016 showed a minimum value of lead (1.403 µg/L) and Dhoom Manikpur water quality station in year 2018 showed a maximum value of lead (3.834 µg/L). Mean value of lead was found maximum in industrial zone of study area. The decreasing order of mean value of lead in study area is 3.493 µg/L (industrial zone) > 3.178 µg/L (agricultural zone) > 2.551 µg/L (residential zone).

Percent change in lead value from pre-monsoon to post-monsoon period showed decrease in lead concentration after precipitation. Recharging of ground aquifers with rain water and evaporation are the two opposing factors which decide the composition of groundwater.

The empirical probability distribution plots of lead content in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.2.2.26, 5.2.2.27 and 5.2.2.28 respectively. The obtained results of lead content of groundwater were also depicted in Box and Whisker plot (Fig. 5.2.2.29). In year 2016 it was found maximum at Khera Dharampura water quality station and in year 2017 & 2018 the maximum lead concentration was observed at Bishnuli water quality station. During whole study period, Sadopur station showed minimum concentration of lead in groundwater. GIS map of lead content in groundwater of study area showed that in year 2016, a small area of industrial zone have higher lead content in groundwater but in year 2017 & 2018, it spread into a comparatively larger part of industrial area (Fig. 5.2.2.30).

The acceptable limit for lead in drinking water, according to Indian Standard Drinking Water-Specification is 0.01 mg/L (10 µg/L) and there is no relaxation. There is no health based guideline value for lead however a provisional guideline value of 10 µg/L is given by WHO on the basis of treatment performance and analytical achievability (WHO 2017). Consumption of water, rich in lead, have various effects on human body like neural disorders, impaired kidney function, impaired fertility, birth abnormalities and cardiovascular disorders. All the analysed samples were well below the standard value of lead given by BIS and WHO. Majolagbe et al., 2017 reported a range of 0 to 1 µg/L in groundwater of in Lagos, Nigeria. Kumar et al., (2017) analysed lead content of groundwater (0 to 200 µg/L) in industrial area of Uttar Pradesh. Potential health risks on humans on consumption of lead rich water were analysed by many researchers in different parts of world (Attisha et al., 2016; Belkhiri et al., 2017; Vetrimurugan et al., 2017; Saha et al., 2017).

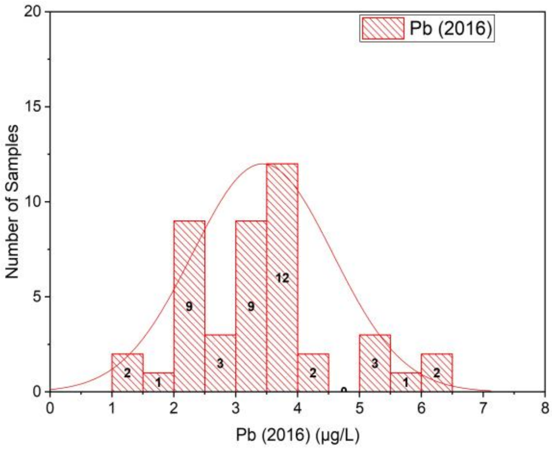


Fig. 5.2.2.26 Empirical probability distribution of Lead concentration in Groundwater samples (in year 2016)

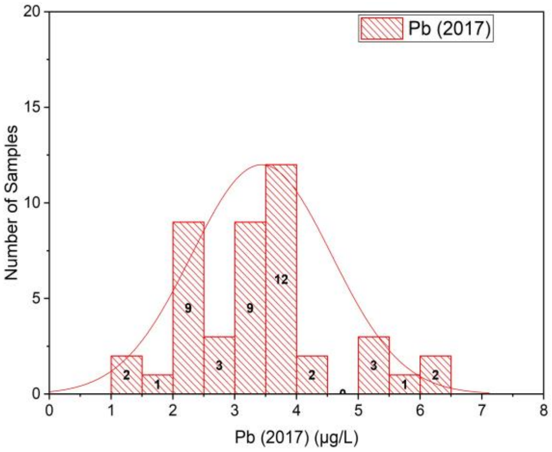


Fig. 5.2.2.27 Empirical probability distribution of Lead concentration in Groundwater samples (in year 2017)

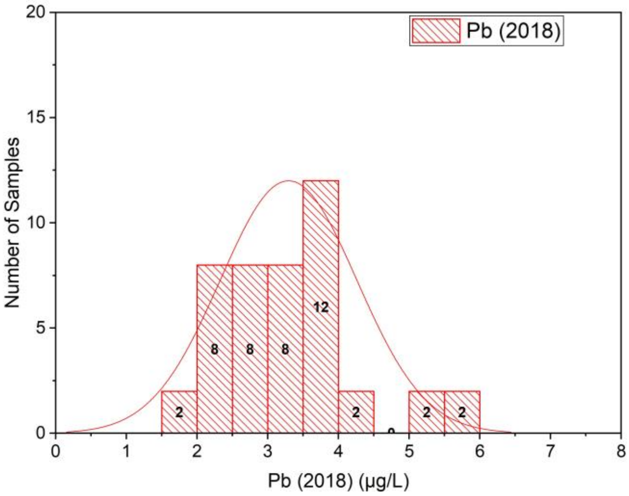


Fig. 5.2.2.28 Empirical probability distribution of Lead concentration in Groundwater samples (in year 2018)

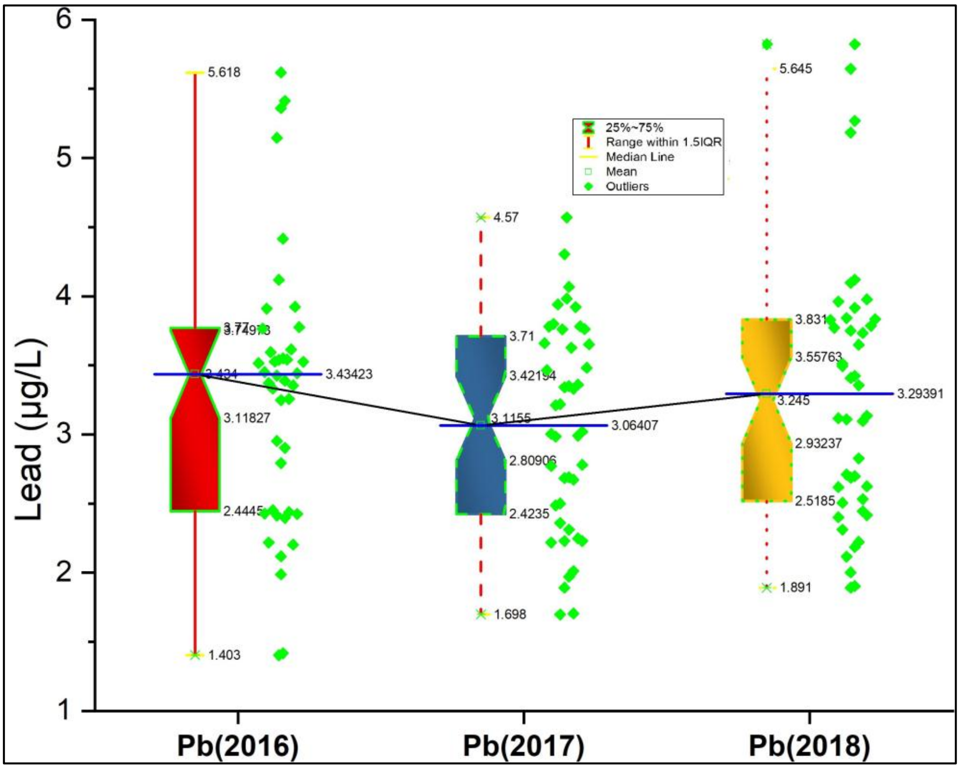
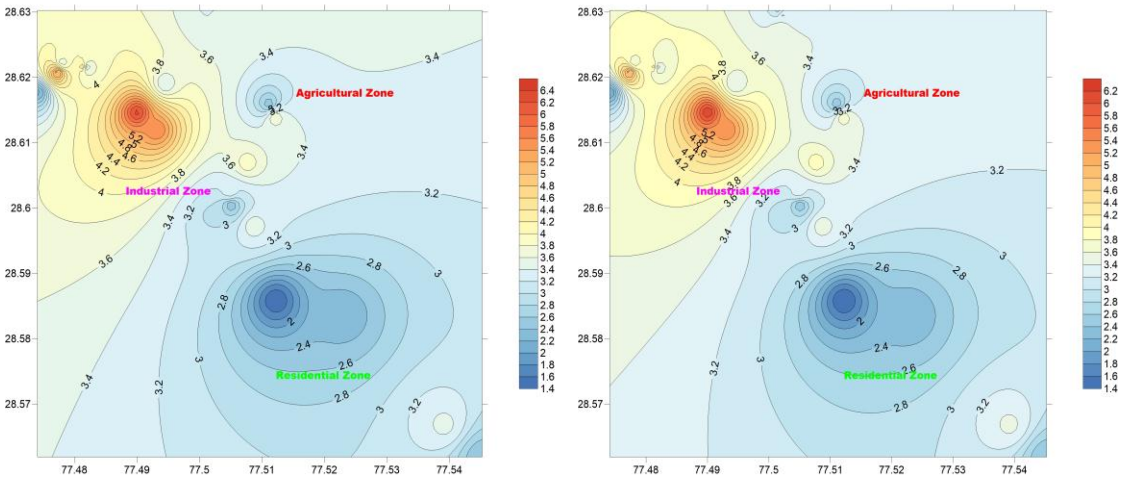
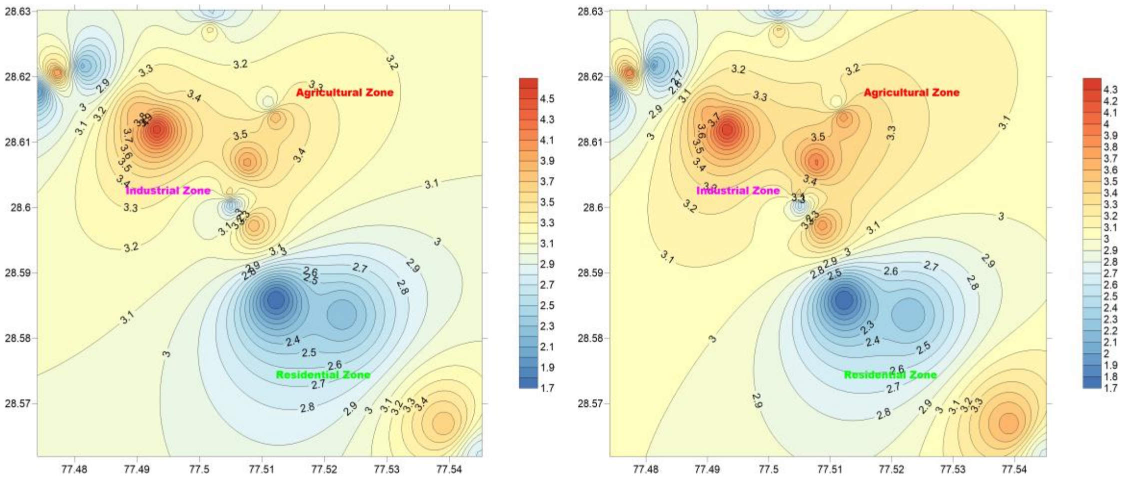


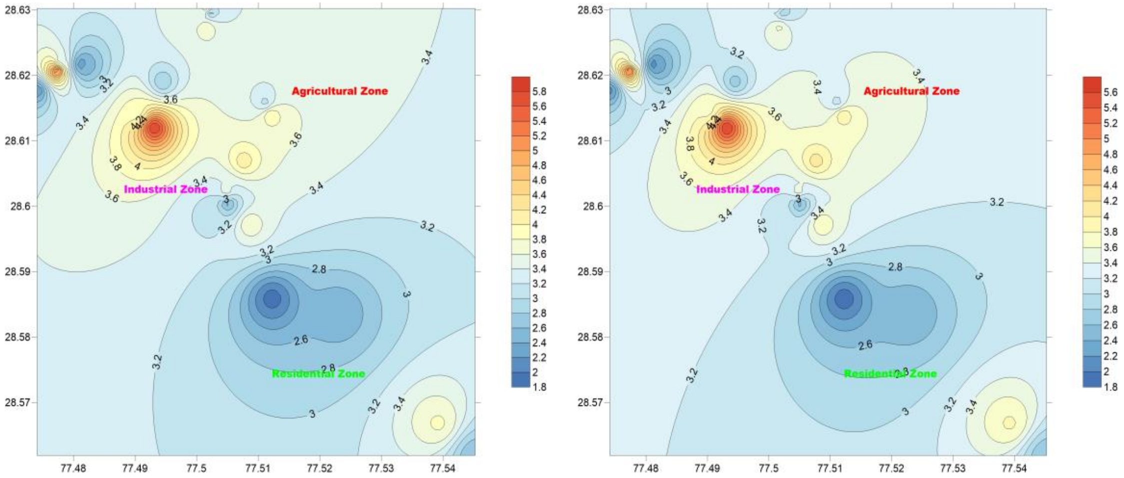
Fig. 5.2.2.29 Box and Whisker plot of Lead concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) **2016 (Post-Monsoon)**



2017 (Pre-Monsoon) **2017 (Post-Monsoon)**



2018 (Pre-Monsoon) **2018 (Post-Monsoon)**

Fig. 5.2.2.30 Spatial distribution of Lead in Groundwater samples during study period (2016-2018)

5.2.2.7 Iron

It is the most abundant heavy metal and fourth most abundant metal in the earth crust. It is found in the environment in both organic and inorganic (mainly as Fe II or Fe III) state. The major minerals of iron are hematite, magnetite, taconite and pyrite. In alkaline water, iron forms insoluble oxides and hydroxides which comes to the surface. In groundwater, iron may be found in soluble ferrous state due to anaerobic conditions. Iron is an essential element for living beings as it is an important component of cytochromes, porphyrins and metalloenzymes. It is an integral part of hemoglobin molecule. Iron deficiency is very likely seen in infants, children and pregnant women. A daily intake of 6 to 30 mg of iron (depends upon the age and sex) is recommended for a healthy person. However intake of excessive amount of iron causes hemochromatosis in humans. In this disease, due to accumulation of iron, regulatory mechanisms do not work properly and results into tissue damage. Excessive consumption of iron present in alcoholic beverages also leads tissue damage (Mesı´as et al., 2013; Central Water Commission (CWC), 2014).

During study period, analytical results of iron in all twenty-two groundwater samples are given in Table – 5.2.2.13 and 5.2.2.14.

The analytical results of iron analysis during study period ranged from 0.071 to 0.692 mg/L. Its minimum value was obtained from pre-monsoon samples of year 2016 at Sadopur water quality station and maximum value was found in groundwater samples of pre-monsoon season of year 2018 at Bisrakh Road station with a mean value of 0.312 mg/L. During 2016, iron concentration ranged from 0.071 to 0.675 with a mean of 0.316 ± 0.154 mg/L. In year 2017, the base value of 0.086 mg/L was obtained from Sadopur station and maximum value (0.687 mg/L) was obtained from Bisrakh Road station. The range of iron, in year 2018, was 0.121 to 0.692 mg/L with mean 0.338 mg/L. During study period the maximum mean value of iron was obtained in year 2018.

Table – 5.2.2.13 Seasonal Variation in Iron concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	0.661	0.578	0.561	-2.12%	7.61%	-3.74%
			Post-monsoon	0.675	0.534	0.582			
	S2	Duryai	Pre-monsoon	0.541	0.484	0.498	-2.03%	0.62%	-0.60%
			Post-monsoon	0.552	0.481	0.501			
	S3	Duryai	Pre-monsoon	0.231	0.116	0.243	-2.16%	-4.31%	1.23%
			Post-monsoon	0.236	0.121	0.24			
	S4	Talabpur	Pre-monsoon	0.31	0.201	0.241	-6.77%	-27.36%	0.41%
			Post-monsoon	0.331	0.256	0.24			
Industrial	S5	Bisrakh Road	Pre-monsoon	0.121	0.094	0.212	-11.57%	-10.64%	0.94%
			Post-monsoon	0.135	0.104	0.21			
	S6	Bisrakh Road	Pre-monsoon	0.488	0.518	0.515	-2.46%	-0.39%	-2.91%
			Post-monsoon	0.5	0.52	0.53			
	S7	Bisrakh Road	Pre-monsoon	0.526	0.687	0.692	-0.76%	2.04%	1.59%
			Post-monsoon	0.53	0.673	0.681			
	S8	Bisrakh Road	Pre-monsoon	0.326	0.233	0.373	2.45%	-3.86%	-2.41%
			Post-monsoon	0.318	0.242	0.382			
	S9	Bisrakh Road	Pre-monsoon	0.278	0.119	0.283	8.27%	-7.56%	-0.71%
			Post-monsoon	0.255	0.128	0.285			
	S10	Khera Dharampura	Pre-monsoon	0.241	0.163	0.256	-3.73%	-22.09%	-5.47%
			Post-monsoon	0.25	0.199	0.27			
	S11	Bishnuli	Pre-monsoon	0.285	0.183	0.266	-2.81%	-3.83%	-2.63%
			Post-monsoon	0.293	0.19	0.273			
	S12	Achheja	Pre-monsoon	0.356	0.371	0.385	-1.40%	-1.89%	-0.52%
			Post-monsoon	0.361	0.378	0.387			
	S13	Achheja	Pre-monsoon	0.24	0.119	0.231	0.83%	-3.36%	-1.73%
			Post-monsoon	0.238	0.123	0.235			
	S14	Dujana	Pre-monsoon	0.448	0.438	0.515	-0.67%	-0.91%	-1.36%
			Post-monsoon	0.451	0.442	0.522			
	S15	Dujana	Pre-monsoon	0.286	0.294	0.315	5.24%	4.42%	4.13%
			Post-monsoon	0.271	0.281	0.302			
	S16	Dujana	Pre-monsoon	0.517	0.506	0.582	-2.32%	-4.94%	-1.72%
			Post-monsoon	0.529	0.531	0.592			
	S17	Dujana	Pre-monsoon	0.178	0.181	0.231	0.56%	2.76%	1.30%
			Post-monsoon	0.177	0.176	0.228			
	S18	Badalpur	Pre-monsoon	0.261	0.211	0.278	-0.77%	-3.32%	-0.72%
			Post-monsoon	0.263	0.218	0.28			
Residential	S19	Sadopur	Pre-monsoon	0.071	0.086	0.121	-15.49%	-6.98%	-7.44%
			Post-monsoon	0.082	0.092	0.13			
	S20	Dairy Maccha	Pre-monsoon	0.187	0.19	0.214	-0.53%	-1.58%	-1.87%
			Post-monsoon	0.188	0.193	0.218			
	S21	Dhoom Manikpur	Pre-monsoon	0.192	0.199	0.195	1.04%	-3.02%	-1.54%
			Post-monsoon	0.19	0.205	0.198			
	S22	Badhpura	Pre-monsoon	0.162	0.173	0.183	1.23%	0.58%	-1.09%
			Post-monsoon	0.16	0.172	0.185			

Table – 5.2.2.14 Statistical Summary of Iron (in mg/L) in Groundwater samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.071	Sadopur	0.082	Sadopur	0.086	Sadopur	0.092	Sadopur	0.121	Sadopur	0.130	Sadopur
Max.	0.661	Duryai	0.675	Duryai	0.687	Bisrakh Road	0.673	Bisrakh Road	0.692	Bisrakh Road	0.681	Bisrakh Road
Mean	0.314		0.318		0.279		0.285		0.336		0.340	
St. Dev.	0.154		0.157		0.177		0.171		0.156		0.157	

In agricultural zone of study area, iron content of water extended from 0.116 to 0.675 mg/L with a mean value of 0.392 mg/L. Most of the samples in agricultural area exceeded the standard limit of iron given by BIS (0.3 mg/L). In industrial zone, iron content of groundwater was 0.094 to 0.692 mg/L with a mean of 0.330 mg/L. A wide variation was observed in iron content of water samples. Out of samples of five water quality stations at Bisrakh Road, samples of two stations (S5 & S9) always had iron concentration below the standard value of BIS. In year 2017, one sample S8 also showed suitability of water for drinking. Rests of the samples from Bisrakh Road station have iron concentration higher than 0.3 mg/L. The reason of high iron content of groundwater was the presence of drainage coming from nearby industries (iron and steel industry, fabric dyeing, paper industry etc.). Water samples of Khera Dharampura, Bishnuli, Achheja (S13), Dujana (S15, S17) and Badalpur were fit for drinking purpose. In residential zone, range of iron was from 0.071 to 0.218 mg/L with a mean of 0.166 mg/L.

On the basis of percent change in iron content of groundwater from pre-monsoon to post-monsoon season, it is concluded that iron content increased after rainfall. Composition of infiltrating water gives a major contribution in metal concentration of water. In current study area, many small drains were coming from the industries. In rainy season dissolution of metal increased with rain water and consequently percolation of metal rich water enhanced the metal concentration of ground aquifers.

Distribution plot and Box-Whisker plot of iron concentration in groundwater samples throughout the study period (2016, 2017 & 2018) at all twenty-two water quality stations are presented in Fig. 5.2.2.31, 5.2.2.32, 5.2.2.33 & 5.2.2.34 respectively. Most of the analysed samples were in range of 0.1 to 0.3 mg/L of iron. Spatial distribution map of iron content of groundwater in study area also showed relative level of iron at studied water quality stations (Fig. 5.2.2.35).

Iron can be naturally present in groundwater in Fe (II) state without giving any colour to it. But on exposure to air, iron converts into Fe (III) and gives an unacceptable reddish-brown colour to water. High concentration of iron gives rusty appearance to water. Occurrence of iron in water also enhances the growth of iron bacteria. Water with high iron content imparts stains to clothes and sanitary-ware. Indian Standard Drinking Water-Specification gives a guideline value of 0.3 mg/L of iron in safe drinking water with no relaxation. No health-based guideline value is given by WHO for iron content of drinking water. The iron content above 0.3 mg/L imparts unpleasant taste to water (WHO, 2017). Out of total analysed samples, nearly 37.8% of samples have iron content higher than the standard value of 0.3 mg/L given by BIS. Anake et al., (2014) analysed a range of 0.11 to 1.41 mg/L in borehole and well water of Ota, Nigeria. Kumar et al., (2017) documented a range of iron concentration from 0.04 to 12.7 mg/L in groundwater of Chhaprola region of Gautam Budh Nagar district.

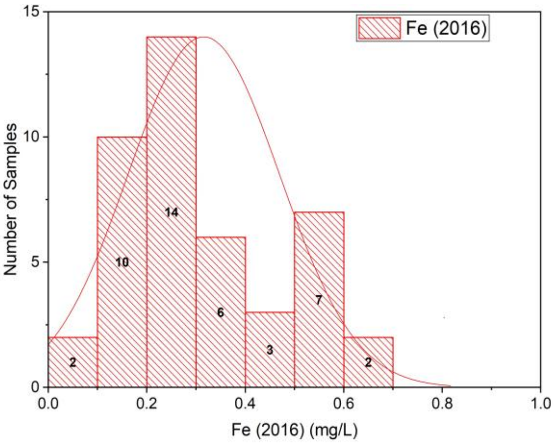


Fig. 5.2.2.31 Empirical probability distribution of Iron concentration in Groundwater samples (in year 2016)

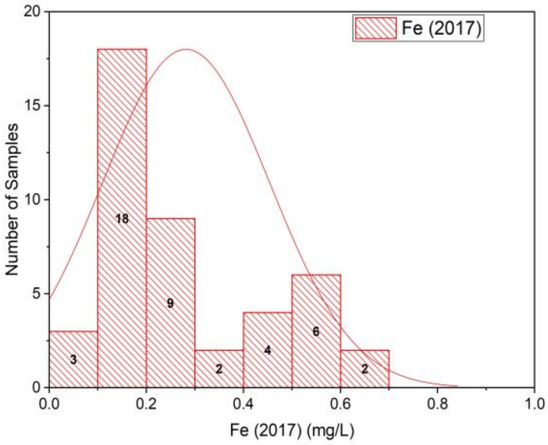


Fig. 5.2.2.32 Empirical probability distribution of Iron concentration in Groundwater samples (in year 2017)

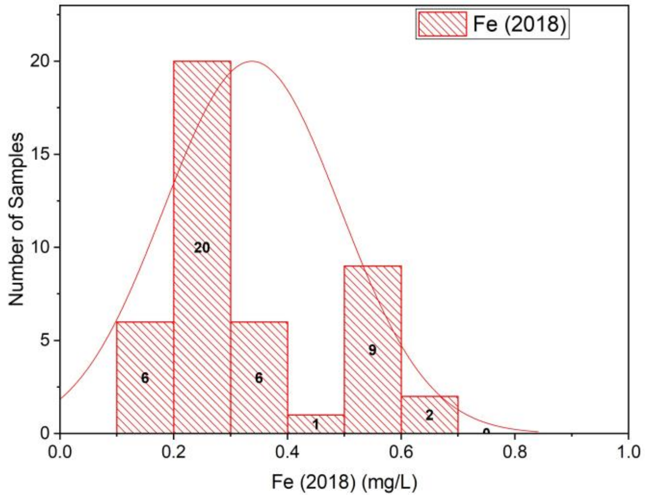


Fig. 5.2.2.33 Empirical probability distribution of Iron concentration in Groundwater samples (in year 2018)

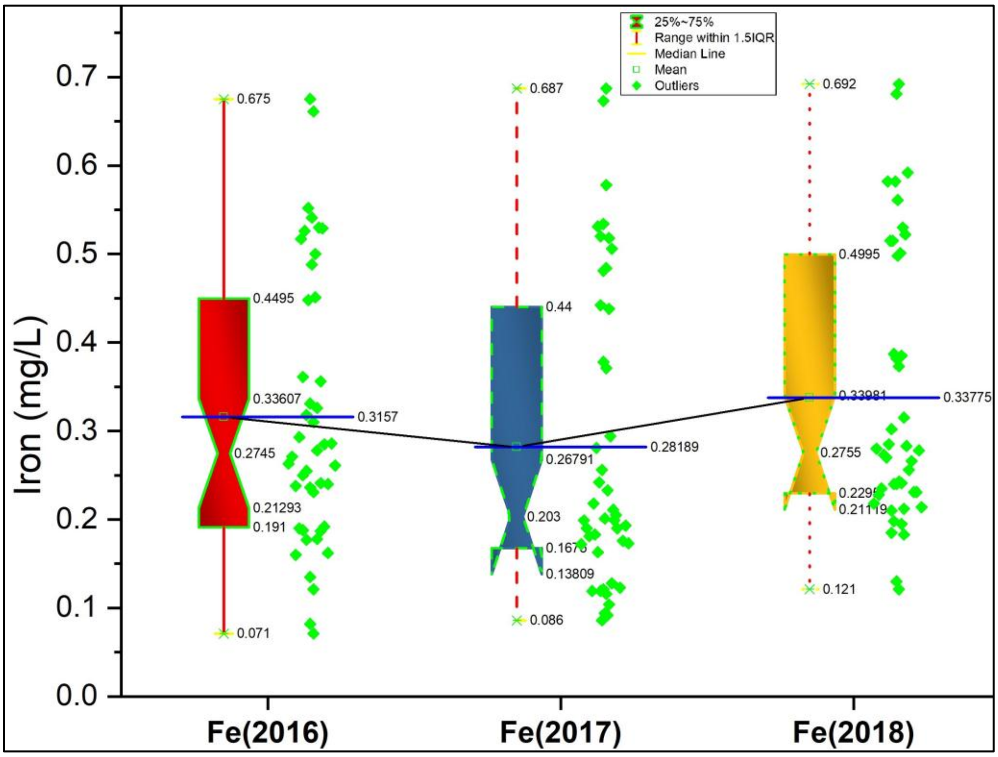
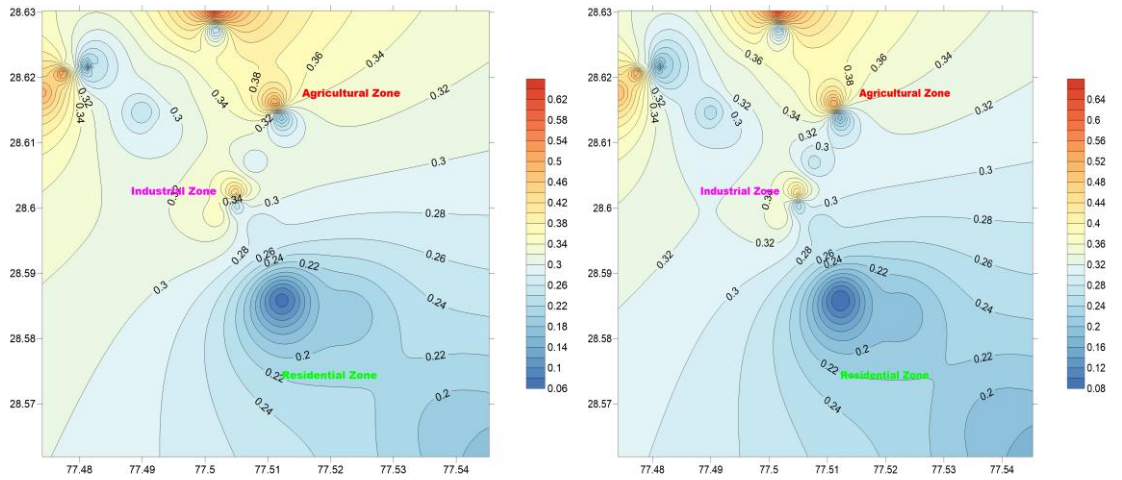
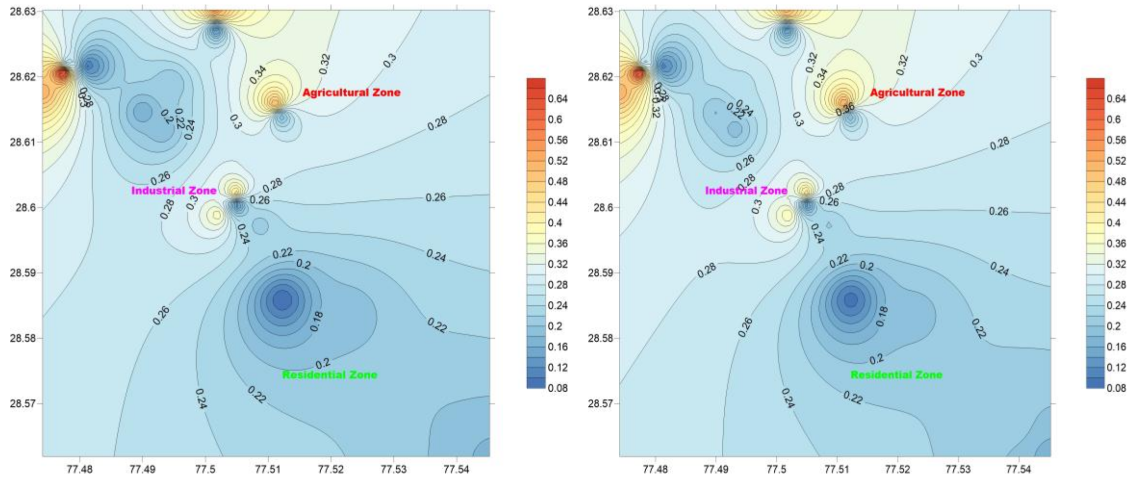


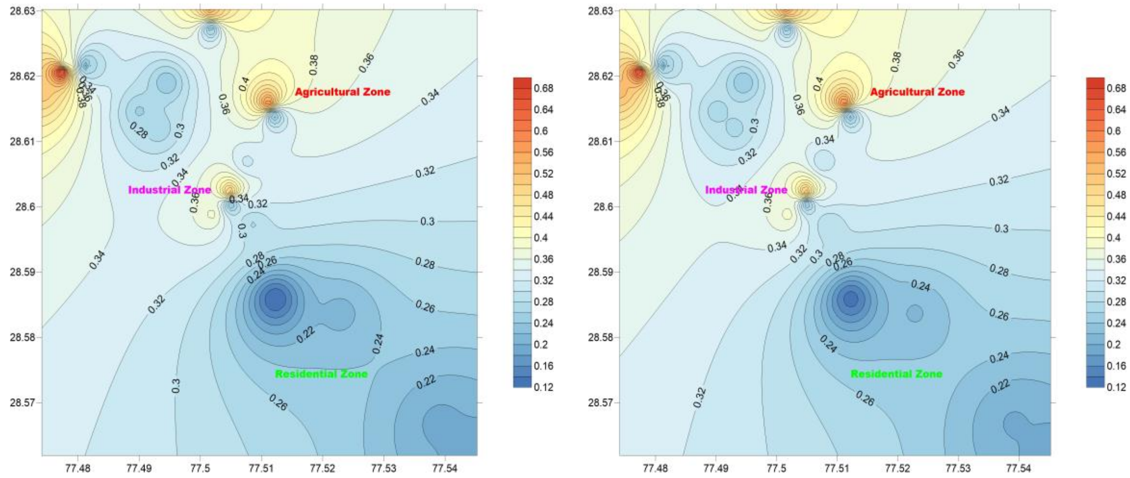
Fig. 5.2.2.34 Box and Whisker plot of Iron concentration in Groundwater samples during study period (2016-2018)



2016 (Pre-Monsoon) 2016 (Post-Monsoon)



2017 (Pre-Monsoon) 2017 (Post-Monsoon)



2018 (Pre-Monsoon) 2018 (Post-Monsoon)

Fig. 5.2.2.35 Spatial distribution of Iron in Groundwater samples during study period (2016-2018)

5.2.2.8 Zinc

Zinc element has twenty-fifth number in series of most abundant elements on earth. As zinc and its oxides are less soluble in water hence its minute quantity is present in natural water bodies. The most common mineral of zinc is zinc blende (ZnS) which is found in nature in association with the sulfide ores of other metals. The major source of zinc in environment is electroplating industries, mining and iron-steel factories. The effluent of plating industry introduces a considerable amount of metal in water aquifers. Use of galvanized containers for cooking food adds a substantial amount of zinc in human body. Zinc is essential for biological activities in all living beings. Many enzymes and proteins, which are necessary for replication and translation of DNA, contain zinc. Zinc acts as a cofactor of carboxypeptidase enzyme (cleaves the peptide bond) and carbonic anhydrase enzyme (present in red blood cells and used in respiration at tissue level) in humans. Small quantity of zinc is required for a healthy person (4 to 10 mg/day; depending upon the age) and pregnant women require up to 16 mg/day. Various plant products (whole grains, nut, seeds, leguminous fruits etc.) and animal products (red meat, shellfishs, dairy product etc.) supply the adequate quantity of zinc to a healthy person. In minute quantity, zinc is non-toxic but if its concentration is higher than 25 mg/L, it causes many health disorders. Excessive intake of zinc results into impairment of growth and reproduction (Institute of Environmental Conservation and Research INECAR, 2000). Symptoms of zinc toxicity include vomiting, diarrhea, icterus, hepatic failure, kidney failure as well as anemia.

During study period, analytical results of zinc in all twenty-two groundwater samples are given in Table – 5.2.2.15 and 5.2.2.16.

During study period of three years, zinc content in analysed samples ranged from 0.008 mg/L (at Dairy Maccha station in pre-monsoon sample of year 2016) to 2.637 mg/L (at Bisrakh Road station in pre-monsoon sample of year 2018) with a mean value of 0.287 ± 0.574 mg/L. During year 2016, zinc content of groundwater varied from 0.008 to 2.361 mg/L with a mean of 0.274 mg/L. Its maximum concentration was found at Bisrakh Road water quality station. In year 2017 and 2018, zinc content was analysed from 0.0082 to 2.528 mg/L and 0.0102 to 2.637 mg/L respectively.

Table – 5.2.2.15 Seasonal Variation in Zinc concentration (in mg/L) of Groundwater samples during year 2016, 2017 & 2018

Zone	Sample No.	Water Quality Station	Season	2016	2017	2018	Percentage change from Pre-monsoon to Post-monsoon		
Agricultural	S1	Duryai	Pre-monsoon	0.0412	0.0241	0.0285	2.18%	1.66%	4.91%
			Post-monsoon	0.0403	0.0237	0.0271			
	S2	Duryai	Pre-monsoon	0.0295	0.0286	0.0268	4.41%	2.45%	5.60%
			Post-monsoon	0.0282	0.0279	0.0253			
	S3	Duryai	Pre-monsoon	0.0325	0.0319	0.0295	2.15%	5.02%	4.07%
			Post-monsoon	0.0318	0.0303	0.0283			
	S4	Talabpur	Pre-monsoon	0.0341	0.0227	0.0432	3.81%	7.49%	6.94%
			Post-monsoon	0.0328	0.021	0.0402			
Industrial	S5	Bisrakh Road	Pre-monsoon	0.0988	0.1081	0.1103	1.32%	3.98%	0.73%
			Post-monsoon	0.0975	0.1038	0.1095			
	S6	Bisrakh Road	Pre-monsoon	0.0981	0.0929	0.1031	1.33%	1.94%	2.04%
			Post-monsoon	0.0968	0.0911	0.101			
	S7	Bisrakh Road	Pre-monsoon	1.365	1.285	1.7	3.96%	1.09%	2.65%
			Post-monsoon	1.311	1.271	1.655			
	S8	Bisrakh Road	Pre-monsoon	2.361	2.528	2.637	3.68%	2.89%	5.20%
			Post-monsoon	2.274	2.455	2.5			
	S9	Bisrakh Road	Pre-monsoon	0.261	0.311	0.341	6.13%	7.40%	4.69%
			Post-monsoon	0.245	0.288	0.325			
	S10	Khera Dharampura	Pre-monsoon	0.2165	0.2312	0.2671	0.79%	0.43%	0.45%
			Post-monsoon	0.2148	0.2302	0.2659			
	S11	Bishnuli	Pre-monsoon	0.0547	0.0345	0.0335	1.46%	4.64%	5.97%
			Post-monsoon	0.0539	0.0329	0.0315			
	S12	Achheja	Pre-monsoon	0.0919	0.0916	0.0925	1.52%	1.53%	0.76%
			Post-monsoon	0.0905	0.0902	0.0918			
	S13	Achheja	Pre-monsoon	0.1043	0.1003	0.1018	1.44%	0.80%	1.08%
			Post-monsoon	0.1028	0.0995	0.1007			
	S14	Dujana	Pre-monsoon	0.0873	0.0418	0.0512	0.92%	3.35%	1.76%
			Post-monsoon	0.0865	0.0404	0.0503			
	S15	Dujana	Pre-monsoon	0.1644	0.174	0.1785	0.36%	0.52%	0.78%
			Post-monsoon	0.1638	0.1731	0.1771			
	S16	Dujana	Pre-monsoon	0.0211	0.0236	0.0301	3.79%	3.81%	1.33%
			Post-monsoon	0.0203	0.0227	0.0297			
	S17	Dujana	Pre-monsoon	0.0331	0.0345	0.0451	3.93%	2.90%	3.10%
			Post-monsoon	0.0318	0.0335	0.0437			
	S18	Badalpur	Pre-monsoon	0.1002	0.1007	0.1032	0.00%	0.20%	1.45%
			Post-monsoon	0.1002	0.1005	0.1017			
Residential	S19	Sadopur	Pre-monsoon	0.1432	0.1441	0.1497	0.28%	0.83%	1.00%
			Post-monsoon	0.1428	0.1429	0.1482			
	S20	Dairy Maccha	Pre-monsoon	0.008	0.0083	0.0105	-1.25%	1.20%	2.86%
			Post-monsoon	0.0081	0.0082	0.0102			
	S21	Dhoom Manikpur	Pre-monsoon	0.7618	0.7713	0.7854	0.17%	0.04%	0.17%
			Post-monsoon	0.7605	0.771	0.7841			
	S22	Badhpura	Pre-monsoon	0.0161	0.0096	0.0172	4.97%	4.17%	4.07%
			Post-monsoon	0.0153	0.0092	0.0165			

Table – 5.2.2.16 Statistical Summary of Zinc (in mg/L) in Groundwater samples

Year	**2016**				**2017**				**2018**			
Season	**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**		**Pre-monsoon**		**Post-monsoon**	
Min.	0.008	Dairy Maccha	0.0081	Dairy Maccha	0.0083	Dairy Maccha	0.0082	Dairy Maccha	0.0105	Dairy Maccha	0.0102	Dairy Maccha
Max.	2.361	Bisrakh Road	2.274	Bisrakh Road	2.528	Bisrakh Road	2.455	Bisrakh Road	2.637	Bisrakh Road	2.5	Bisrakh Road
Mean	0.278		0.270		0.282		0.276		0.313		0.303	
St. Dev.	0.558		0.538		0.583		0.569		0.640		0.612	

Analytical results of study revealed that in agricultural zone, zinc content ranged between 0.021 mg/L (in post-monsoon sample of 2017 collected from Talabpur) and 0.0432 mg/L (in pre-monsoon sample of year 2018 collected from Talabpur). Industrial zone of study area has slightly higher value of zinc content. In industrial zone it ranged from 0.0203 to 2.637 mg/L. The higher value of zinc in groundwater of Bisrakh Road water quality station can be attributed to presence of fabric dyeing industry and paper mill in nearby area.

Percent change in zinc value from pre-monsoon to post-monsoon season showed slight dilution of ground aquifers in terms of metal concentration. Samples collected from Dairy Maccha water quality station in year 2016 showed negligible rise in concentration of zinc in post-monsoon season.

Results of zinc analysis in groundwater samples, throughout the study period (2016, 2017 & 2018) at all twenty-two water quality stations, are presented through distribution plot & Box-Whisker plot (Fig. 5.2.2.36, 5.2.2.37, 5.2.2.38 & 5.2.2.39). The mean concentration of zinc gradually increased from year 2016 to 2018 (0.274 mg/L < 0.279 mg/L < 0.308 mg/L). GIS map of zinc concentration of groundwater in study area is given in Fig. 5.2.2.40.

BIS sets an acceptable limit of 5 mg/L of zinc for drinking water and a permissible limit of 15 mg/L in absence of alternative source. WHO does not give any health based guideline value for zinc in drinking water. However it gives a taste threshold value of 4 mg/L. Higher concentration of zinc in drinking water gives an unpleasent taste to it. Zinc content of household water supply can be higher due to dissolution of zinc from the galvanized pipes. On the basis of BIS standards all the analysed samples were well below from the acceptable limit of zinc. Mansouri et al., (2012) reported mean concentration of Cd, Pb, Cr, Cu, Zn and Fe in groundwater of Birjand Flood Plain of Iran- 0.000, 0.023, 0.049, 0.109, 0.192 and 0.174 mg/L respectively. Bhattacharya et al., (2017) analysed zinc concentration (0.003 to 1.438 mg/L) in groundwater of Durgapur, West Bengal and concluded that all the samples were within the prescribed limit of zinc by WHO.

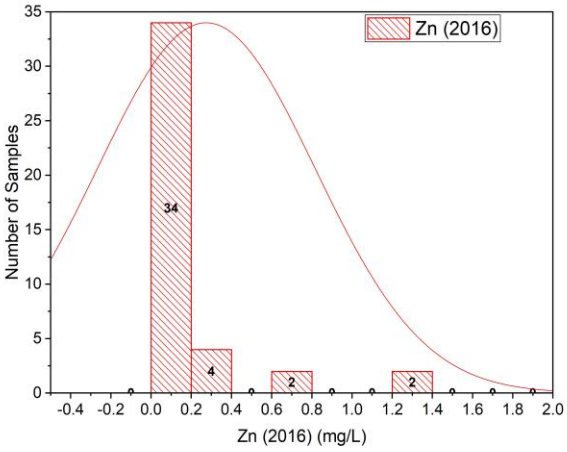


Fig. 5.2.2.36 Empirical probability distribution of Zinc concentration in Groundwater samples (in year 2016)

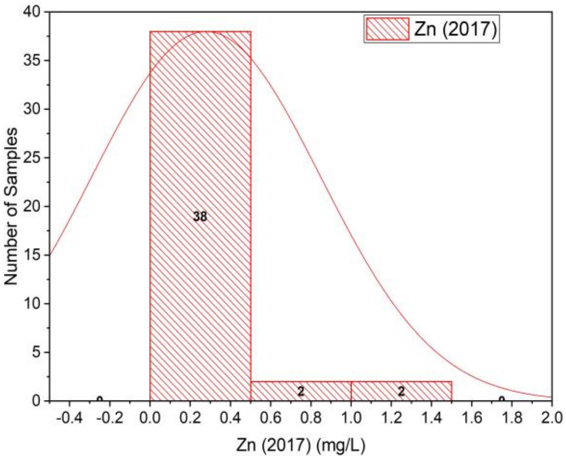


Fig. 5.2.2.37 Empirical probability distribution of Zinc concentration in Groundwater samples (in year 2017)

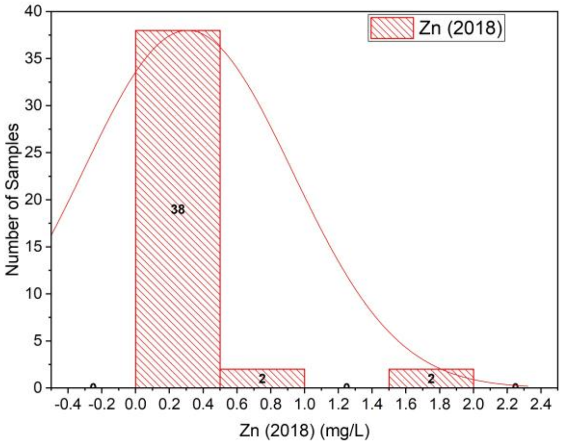


Fig. 5.2.2.38 Empirical probability distribution of Zinc concentration in Groundwater samples (in year 2018)

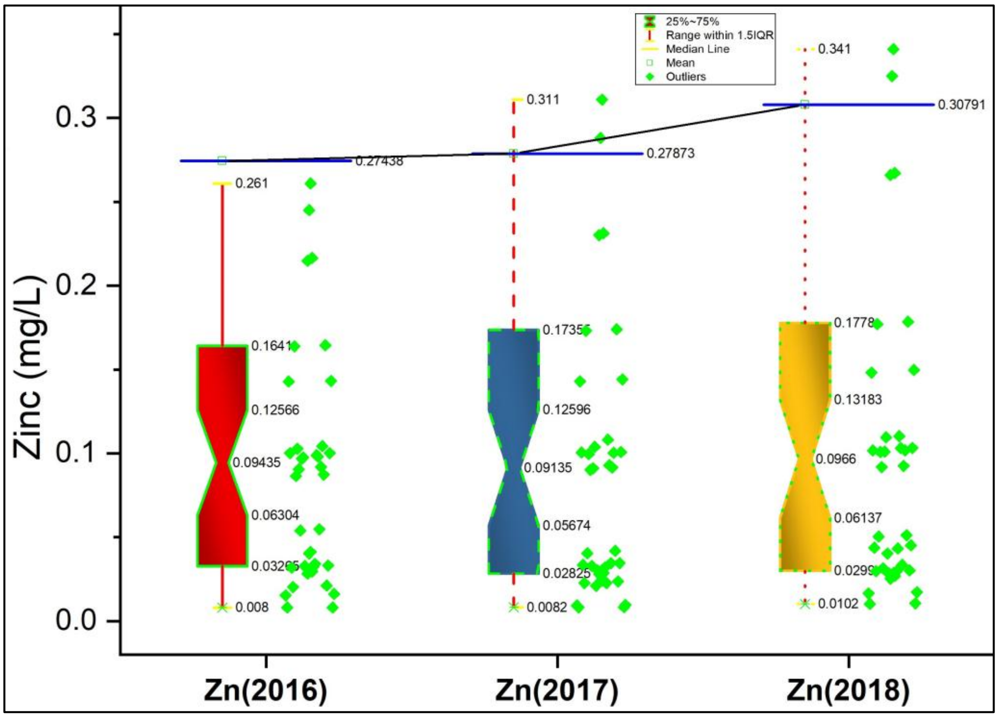
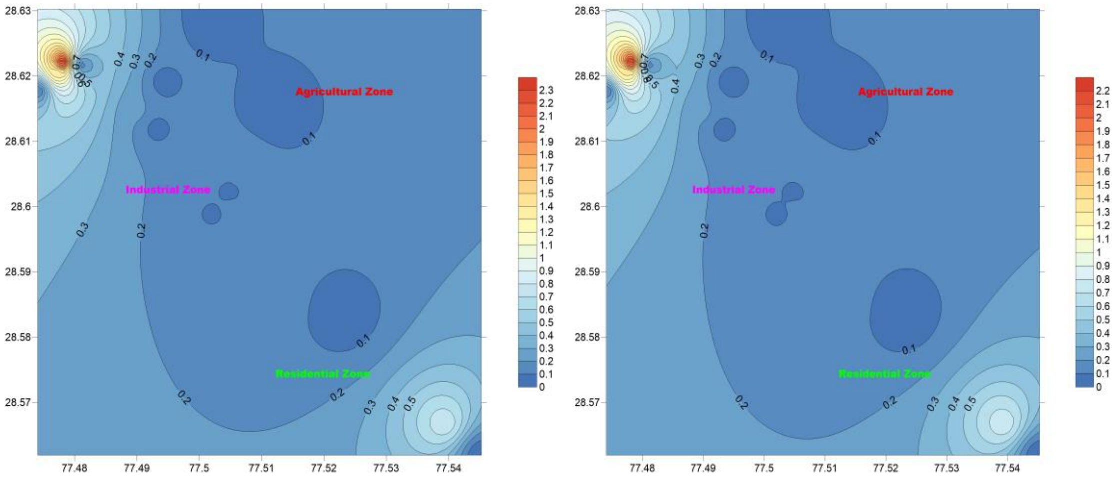
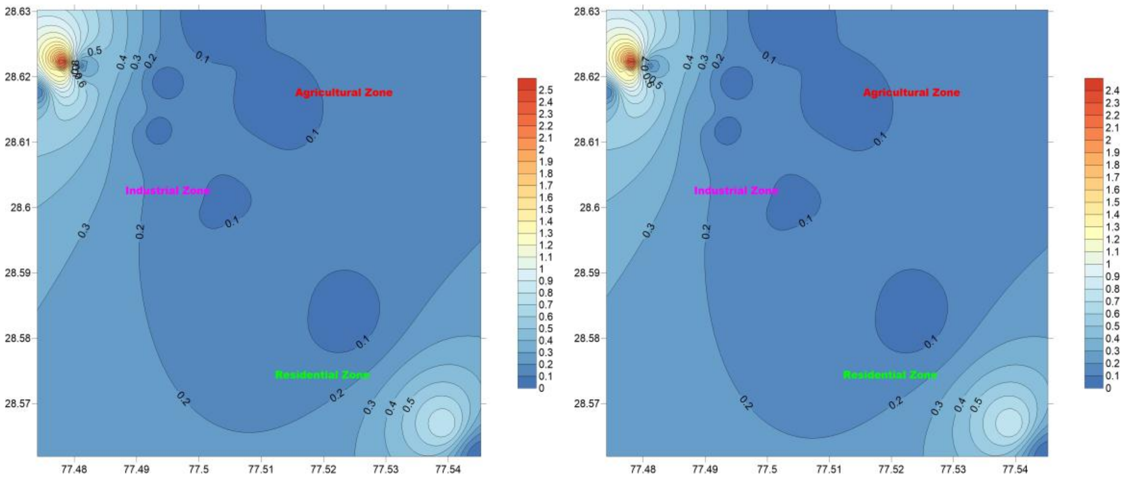


Fig. 5.2.2.39 Box and Whisker plot of Zinc concentration in Groundwater samples during study period (2016-2018)



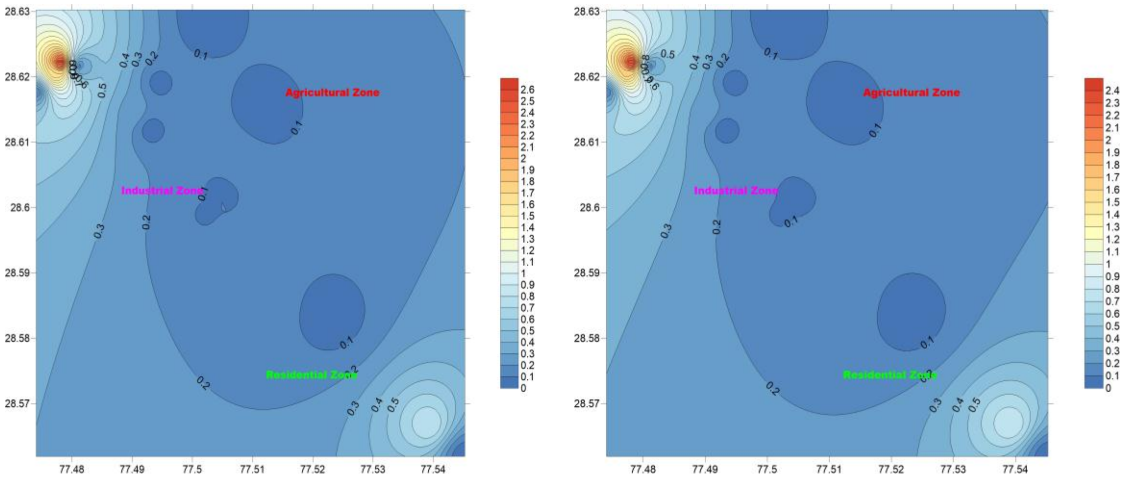
2016 (Pre-Monsoon)

2016 (Post-Monsoon)



2017 (Pre-Monsoon)

2017 (Post-Monsoon)



2018 (Pre-Monsoon)

2018 (Post-Monsoon)

Fig. 5.2.2.40 Spatial distribution of Zinc in Groundwater samples during study period (2016-2018)

SUMMARY

Mean values of pH, electrical conductivity, total dissolved solids, turbidity, total hardness, calcium, magnesium, sodium, potassium, boron, total alkalinity, chloride, fluoride, nitrite, nitrate, phosphate, sulphate and ammonia in groundwater were; 7.80, 1556 µmhos/cm, 1011 mg/L, 8 NTU, 406 mg/L, 63.02 mg/L, 62.52 mg/L, 120.2 mg/L, 23.69 mg/L, 1.04 mg/L, 251.2 mg/L, 135.2 mg/L, 0.59 mg/L, 0.24 mg/L, 204 mg/L, 1.11 mg/L, 93.24 mg/L and 0.169 mg/L respectively. pH of analysed samples was neutral to alkaline. Maximum pH (9.15) was obtained from samples of Dujana station. Nearly 11% of samples were out of standard range of pH (6.5 to 8.5). Electrical conductivity and TDS decreased after precipitation. TDS of 83% of samples were beyond the acceptable limit of BIS. Three samples collected from Achheja & Dujana stations were having TDS more than permissible limit of BIS. Higher turbidity was found in samples collected from Bisrakh Road (S7), Dairy Maccha, Dhoom Manikpur and Badhpura stations. Mean total hardness was highest in industrial zone. Total alkalinity of nearly 61% of analysed samples were above the desirable limit of BIS. Two samples of Badhpura station (pre-monsoon season of year 2016 & 2018) exceeded the permissible limit of total alkalinity. Calcium in 34.9% of samples, Magnesium in 100% of samples, Boron in 84% of samples and Chloride in 25.8% of samples were beyond the desirable limit given by BIS. Samples of Bisrakh Road, Khera Dharampura, Achheja & Dhoom Manikpur had magnesium content above permissible limit given by BIS. Geological source of high magnesium content of groundwater was observed in study area. Sodium content of 25.8% of samples were above the taste threshold of WHO. These samples were collected from Achheja, Dujana and Badalpur stations. Higher concentration of potassium was obtained from samples of industrial zone. Boron content was obtained high in agricultural samples. Groundwater samples of Duryai station showed increase in chloride after precipitation. Dissolution of potassium fertilizers KCl (muriate of potash) may be attributed to high chloride content of groundwater in post-monsoon season. Fluoride level of nearly 10.6% of samples exceeded the acceptable limit and 3 samples of industrial zone (Achheja & Dujana) were above the permissible value. Almost 97.7% of samples were beyond the standard value of nitrate for drinking water. Leaching of agricultural waste water and municipal water was responsible for high nitrate content of groundwater. All of analysed samples were within guideline value of nitrite, i.e., 3 mg/L. Phosphate content of samples of agricultural and residential zone was high. Nearly 75% of samples were within acceptable limit of sulphate, i.e., 200 mg/L. Two samples, collected from Achheja station in year 2016, were beyond the permissible limit of sulphate (400 mg/L). Dumping of industrial waste water without treatment enhanced sulphate content of groundwater. Results of ammonia analysis concluded that groundwater of industrial and residential zone was partially fit for drinking. Agriculture zone has safe quality of water in terms of ammonia content.

Obtained range of analysed metals, i.e., Arsenic, cadmium, chromium, copper, Nickel, Lead, Iron & Zinc in groundwater samples throughout study period were 0.518-12.561 µg/L, 0.004-5.997 µg/L, 5.189-40.02 µg/L, 1.005-8.719 µg/L, 0.377-14.560 µg/L, 1.403-6.265 µg/L, 0.071-0.692 mg/L, 0.008-2.637 mg/L respectively. Chromium, copper, nickel, lead & zinc content of 100% analysed samples were within the standard range. About 3% of samples (Bishnuli & Dujana) exceeded the standard range of arsenic. Application of fertilizers and pesticides, disposal and incineration of municipal and industrial waste contribute to arsenic content of groundwater. Nearly 10% of samples (Dujana & Dhoom Manikpur) exceeded the standard range of cadmium. The waste products released from the CHW Forge industry, where forging and flange was carried out, were responsible for contamination of ground aquifers with cadmium. A pipe manufacturing unit was also running in this area. The effluent of the industry also contaminated the water resources. A cement manufacturing unit - Ambuja cement Ltd. was present in Dhoom Manikpur. The dumping of industrial wastes of the industry contributed to the cadmium level in ground aquifers. Out of total, 37.8% of samples (Bisrakh Road & Agricultural zone) exceeded the standard range of iron. The reason of high iron content of groundwater in these samples was the presence of drainage coming from nearby industries (iron and steel industry, fabric dyeing, paper industry etc.).

5.3.1 INTRODUCTION

India is a land of agriculture. Agriculture sector of India comprises 18% of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce (Madhusudhan, 2015). In India, agriculture is not completely rain-fed but it depends on irrigation through other sources. Due to unavailability of surface water throughout the year, groundwater is used for irrigation purpose. In India 85% of required drinking water and 60% of required irrigation water is extracted from ground aquifers (Suhag, 2016).

Various programs have been developed by Indian government to protect quantity and quality of ground aquifers: National project of Aquifers Management (NAQUIM), National Groundwater Management Improvement Program etc. Recently Prime Minister of India launched Atal Bhujal Yojana under Jal Jeevan Mission, on 25th Dec. 2019. Seven states of India; Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh are chosen for the development of groundwater management program. To regulate use of groundwater for irrigation, National Green Tribunal of India suggested registering of borewells across the country.

Gautam Budh Nagar district is situated in Ganga-Yamuna Doab near the capital of India. It is a region of traditional agriculture with extensive population. Although study area gets sufficient rainfall, but due to climatic changes, monsoon pattern has been changed. Especially during the dry season of year, alternative source of irrigation is required. Due to unavailability of surface water in area, people are mainly depend on groundwater for agricultural requirement of water. In last two decades, for the economic growth of this area, a large number of manufacturing industries are established here or shifted from nearby areas of Delhi and Ghaziabad. The waste water of these industries containing the hazardous materials is dumped in nearby water bodies or directly into the ground aquifers without any treatment. Over a period of time toxic substances, present in industrial wastes, contaminate the surface water as well as groundwater. At one hand increasing population, extensive agriculture and industrialization are polluting the water aquifers, but on the other hand due to increasing demand of fresh water for domestic and agriculture practices, the exploitation of groundwater has been increased tremendously. Increasing urbanization also enhanced the pressure on ground aquifers. Available surface water is not sufficient to meet the increased requirement of irrigation water. Groundwater is the alternative source of freshwater for various purposes.

A lot of work has been done in different parts of world to evaluate the suitability of groundwater for irrigation purpose (Wang, 2013; Salifu et al., 2017; Akakuru & Akudinobi, 2018; Park et al., 2018). In India non-selective use of fertilizers, disposal of industrial & household wastes in unplanned manner and over-exploitation of groundwater are causing degradation in the quality of groundwater (Haritash et al., 2008). Various studies in different states of India showed that groundwater of Haryana (Singh et al., 2017), Uttar Pradesh (Tyagi et al., 2009), Punjab (Kumar et al., 2007), Maharashtra (Deshpande & Aher, 2012; Gaikwad et al., 2019), Karnataka (Ravikumar et al., 2011), Telangana (Jampani et al., 2018) and Kerala (Prasanth et al., 2012) is partially fit for irrigation. Highly saline and alkaline irrigation water of these areas degrades the soil quality which directly affects the fertility of soil.

5.3.2 IMPORTANT PARAMETERS FOR IRRIGATIONAL WATER

Groundwater of any area depends upon the geo-environmental conditions of that area. Suitability of groundwater for irrigational purpose measured through the quantity and quality of dissolved ions present in it. A small amount of salts are always present in groundwater due to dissolution of minerals and weathering of rocks. Increasing urbanization and industrialization enhances the content of dissolved ions in underground water. Whenever this water is used in irrigation, these salts remain in soil as water is used up by plants or evaporated. Continuous use of such type of water elevates the concentration of ions in soil. The excessive amount of ions in irrigational water negatively affects the soil structure and plant growth. It is very necessary to assess the appropriateness of irrigational water to maintain the soil productivity and crop yield. Salinity hazard and alkalinity hazard are two critical parameters to evaluate the quality of irrigation water. The suitability of groundwater of Gautam Budh Nagar district in pre-monsoon and post-monsoon samples during study period was evaluated by using the parameters like-

1) Electrical conductivity (EC)
2) Sodium absorption ratio (SAR)
3) Residual sodium carbonate (RSC)
4) Sodium percentage (Na%)

5) Permeability index (PI)
6) Magnesium hazard (MH)
7) Kelly index (KI)
8) Boron toxicity

5.3.2.1 Electrical Conductivity (EC)

Electrical conductivity is the most important irrigational water quality parameter which affects the productivity of soil and crop yield. Generally salt concentration in soil enhanced due to irrigation water. If amount of salts is high enough to adversely affect the crop yield than salinity problem occurs. Water salinity hazard is measured by the electrical conductivity of irrigational water. Irrigational water with high electrical conductivity value makes the soil saline. In saline soil solution, roots are unable to absorb water from the soil. This phenomenon is called as physiological drought (Fipps, 2003). Highly saline water is not good for crop irrigation. Germination of seeds is also affected by the salinity of soil. Seeds cannot imbibe water in saline soil hence rate of germination gets slow down.

EC of groundwater of study area ranged from 520 to 4251 µmhos/cm with a mean value of 1555.5 µmhos/cm (Table – 5.3.1). Its minimum value was obtained from Dujana water quality station in post-monsoon sample of year 2017 and maximum value was found in groundwater of Achheja water quality station in pre-monsoon sample of year 2016.

According to classification given in Table – 4.6, water with EC value lesser than 250 µmhos/cm is excellent for irrigation as it has relatively high amount of Ca, Mg and HCO_3 ions. Groundwater with EC value between 250 & 750 µmhos/cm is termed as good for irrigation. Groundwater is highly saline when its EC value is 750 to 2250 µmhos/cm. This type of water can be utilized for irrigation with special practices of leaching and drainage (Wilcox, 1955). The major crops cultivated in study area were; wheat, barley, bajra, maize, urd, moong, lentil, gram, arhar, mustard etc. These crops are moderate salt tolerance crops hence prolonged irrigation of these crops with saline water required proper leaching with highly permeable soil. Groundwater having EC value greater than 2250 µmhos/cm is unsuitable for irrigation. The classification of studied samples on the basis of electrical conductivity (Wilcox, 1955) is given in Table – 5.3.2.

Table – 5.3.1 Electrical Conductivity of Groundwater Samples during study period

Water Quality Station	Electrical Conductivity (µmhos/cm)					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	1525	1410	1059	1130	1529	1340
Duryai	939	869	845	877	949	835
Duryai	860	796	727	795	871	769
Talabpur	910	883	765	790	1270	1128
Bisrakh Road	710	698	633	658	695	607
Bisrakh Road	2371	2260	1810	2115	2617	2348
Bisrakh Road	2107	2050	1657	1779	1900	1660
Bisrakh Road	917	902	819	811	898	797
Bisrakh Road	780	775	615	706	790	700
Khera Dharampura	1292	1149	1007	1052	1401	1210
Bishnuli	1283	1195	1153	1135	1179	1051
Achheja	4251	4061	1878	2501	2758	2700
Achheja	2330	2252	1650	1939	2298	2038
Dujana	760	682	538	520	943	879
Dujana	2990	2715	1818	2200	2638	2325
Dujana	2845	2763	2102	2648	3448	2990
Dujana	2365	2304	1790	2211	2441	2124
Badalpur	2580	2475	1980	2380	2868	2553
Sadopur	765	760	561	610	660	615
Dairy Maccha	890	831	1222	1328	1491	1320
Dhoom Manikpur	1600	1438	1923	1735	2055	1753
Badhpura	2800	2205	1763	1850	2310	2150
Minimum	710	682	538.00	520.00	660	607
Maximum	4251	4061	2102.0	2648.0	3448	2990
Mean	1721.4	1612.4	1287.05	1444.1	1727.68	1540.55

Table – 5.3.2 Classification of studied groundwater samples based on Electrical Conductivity

EC (µmhos/ cm)	Water Class	Salinity	Percentage of samples					
			2016		2017		2018	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<250	Excellent	Less saline (relatively high proportion of calcium, magnesium & bicarbonate ions)	-	-	-	-	-	-
250-750	Good	Moderately saline having varying concentrations of ions	4.5%	9.1%	22.7%	18.2%	9.1%	13.6%
750-2250	Fair	Highly saline (high proportion of sodium & chloride ions)	59%	59%	77.3%	68.2%	54.5%	63.6%
>2250	Unsuitable	Very highly saline (containing high concentrations of sodium, bicarbonate & carbonate ions)	36.4%	31.8%	-	13.6%	36.4%	18.2%

According to the classification of Wilcox, none of the sample came under excellent type of category. In pre-monsoon season of 2016, 59% of the samples had highly saline water, 36.4% of samples were found unsuitable for irrigation in terms of salinity. After rainy season, 59% of samples had high saline water however less salinity was observed at most of the station. In pre-monsoon season of 2017, nearly 77.3% of samples had highly saline water and 22.7% had fairly good saline water. A wide seasonal variation was observed in salinity of water in 2017. In 2017 after rainy season, 13.6% of samples became unsuitable for irrigation. In 2018, salinity of water increased in comparison of year 2017. About 36.4% and 18.2% of samples found unfit for irrigation in pre and post monsoon season of year 2018 respectively.

Empirical probability distribution plots and box-whisker plot of EC of groundwater samples are given in Fig. 5.2.1.6, 5.2.1.7, 5.2.1.8 & 5.2.1.9.

Nagarajan et al., (2010) investigated irrigation suitability of underground water of Thanjavur city of Tamilnadu and reported a range of 190 to 6000 µmhos/cm of electrical conductivity. They found that 5 samples out of total 102 samples, came under the category of unsuitable type, in terms of salinity hazard. Kumar et al., 2014 examined the salinity of groundwater of Pudunagaram, Palakkad district of Kerala in pre-monsoon (178 to 3380 µmhos/cm) & post-monsoon season (107 to 3000 µmhos/cm) and concluded that salinity reduced after rain-fall. Similar type of studies were carried out by Aghazadeh & Mogaddam, 2010 in Oshnavieh area of Iran; Ishaku et al., 2011 in Jada area of north-eastern Nigeria; Wu & Sun, 2016 in Guanzhong plain of China; Salifu et al., 2017 in upper west region of Ghana; Soleimani et al., 2018 in Sarpol-e Zahab city in Iran. A range of 673 to 3470 µmhos/cm was reported by Jampani et al., (2018) in groundwater of Hyderabad city.

5.3.2.2 Sodium Absorption Ratio (SAR)

The sodium concentration is one of the major constituent for assessment of irrigation quality of water. The high sodium content in water may obstruct the soil permeability. Considering the effects of sodium on soil or sodicity hazard, United State Salinity Laboratory (USSL) introduced a factor Sodium Adsorption Ratio (SAR), based on concentration of sodium, calcium and magnesium. The mathematical expression used for calculation of SAR-

SAR = $\frac{Na}{\sqrt[2]{Ca+Mg/2}}$

Concentration of all the cations were taken in meq/L. SAR is a parameter to evaluate the alkali hazard or sodium hazard of irrigational water. The effect of high sodium concentration relative to calcium and magnesium, on the soil structure, is determined through SAR value. High sodium content of irrigational water gets adsorbed on the soil particles and makes it hard & tough. Long term use of water having high SAR value reduces the permeability of soil and makes it impervious.

According to the classification given by Richards, (1954) and Todd, (1959) water having SAR value lesser than 10 meq/L has low sodicity hazard. Water with SAR in the range of 10 to 18 meq/L produce medium sodicity hazard. Use of such water causes a considerable sodium hazard in fine textured soils with high conductivity. This water may be used on coarse textured organic soil with good permeability and high leaching. Water with SAR value 18 to 26 meq/L may accumulate high levels of sodium in all types of soil and need management of soil conditions with chemical amendments. Highly saline water is not compatible with chemical amendments. The use of high SAR water for irrigation may also cause permeability problems, by clogging of soil (Goyal et al., 2010). Due to reduction in permeability, the rate of water filtration into the soil is reduced upto a great extent. As a result crop is not adequately supplied with water therefore overall yield is reduced.

In current study, measured values of SAR of groundwater samples varied from 0.16 to 5.78 meq/L (Table – 5.3.3). A decline in SAR value was obtained in post-monsoon season of study period (2.6 to 2.4 meq/L in 2016, 2.49 to 2.3 meq/L in 2017 and 2.42 to 2.25 meq/L in 2018). On the basis of SAR value all the analysed samples were excellent for irrigation (Table – 5.3.4).

Table – 5.3.3 Sodium Absorption Ratio (SAR) of Groundwater Samples during study period

Water Quality Station	SAR (meq/L)					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	2.22	2.00	2.92	1.95	2.02	1.86
Duryai	1.37	1.29	1.62	1.44	1.41	1.24
Duryai	1.04	0.96	1.86	1.04	0.98	0.91
Talabpur	0.70	0.68	0.73	0.63	0.78	0.72
Bisrakh Road	1.00	0.96	1.16	1.10	0.93	0.82
Bisrakh Road	3.16	3.07	3.03	2.96	3.35	3.19
Bisrakh Road	2.56	2.53	2.34	2.31	2.33	2.18
Bisrakh Road	1.09	1.04	1.28	0.96	0.93	0.87
Bisrakh Road	0.75	0.70	0.90	0.75	0.74	0.69
Khera Dharampura	0.99	0.84	0.64	0.68	0.94	0.86
Bishnuli	3.07	2.62	3.60	3.39	1.87	1.66
Achheja	4.86	4.69	3.74	3.66	3.81	3.71
Achheja	4.20	4.12	4.02	3.77	4.15	3.86
Dujana	0.43	0.36	0.43	0.33	0.44	0.39
Dujana	3.80	3.82	3.08	3.21	3.75	3.57
Dujana	3.95	3.94	3.91	3.93	4.52	4.18
Dujana	4.21	4.20	3.60	3.62	4.03	4.01
Badalpur	4.40	4.47	3.84	3.87	4.27	3.98
Sadopur	0.20	0.20	0.18	0.17	0.18	0.16
Dairy Maccha	4.63	3.63	3.79	3.60	3.78	3.31
Dhoom Manikpur	2.73	2.31	3.37	3.30	3.45	3.20
Badhpura	5.78	4.89	4.75	4.79	4.58	4.09
Minimum	0.20	0.20	0.18	0.17	0.18	0.16
Maximum	5.78	4.89	4.8	4.8	4.58	4.18
Mean	2.6	2.4	2.49	2.3	2.42	2.25

Table – 5.3.4 Classification of studied groundwater samples based on Sodium Absorption Ratio

SAR (meq/L)	Sodicity Hazard	Percentage of samples					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<10	Low	100%	100%	100%	100%	100%	100%
10-18	Medium	-	-	-	-	-	-
18-26	High	-	-	-	-	-	-
>26	Very High	-	-	-	-	-	-

During the study period, distribution plot of SAR of groundwater samples showed that comparatively greater number of samples were present on the right side of plot in year 2017 and left side of plot in year 2018 (Fig. 5.3.1, 5.3.2 & 5.3.3). This explained that although all of the samples had excellent type of water in terms of SAR value, but in year 2017, a large number of samples showed SAR value near to 4 meq/L. Box and whisker plot of SAR value of groundwater in three consecutive years showed that all the values are within the box and whisker, no outliers are present in it (Fig. 5.3.4). Data is somewhat symmetrical throughout study period.

Similar type of results was obtained by Goyal et al., 2010 in Kaithal district of Haryana (range of SAR 4.5 to 69.4 meq/L in pre-monsoon season & 2.1 to 44.1 meq/L in post-monsoon season). Nagarajan et al., (2010) reported a range of 0.97 to 9.17 meq/L of SAR in Thanjavur city of Tamilnadu. On the basis of SAR values Madhav et al., (2018) in Sant Ravidas Nagar (Bhadohi) in Uttar Pradesh, Gaikwad et al., (2019) in Sindhudurg district of coastal Maharashtra and Adimalla & Venkatayogi, (2018) in Basara region of Adilabad district of Telangana, reported the suitability of groundwater for irrigation. In Malwa region of Punjab eco-friendly agricultural practices were recommended by Ahada & Suthar (2018).

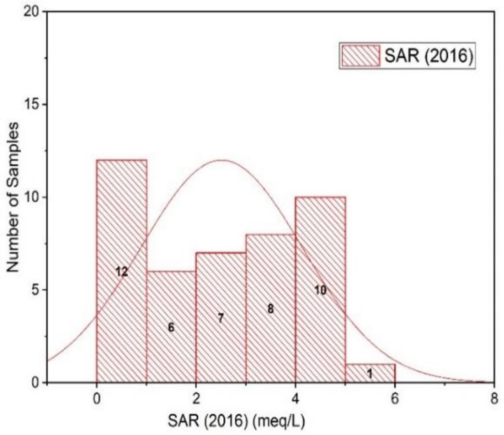


Fig. 5.3.1 Empirical probability distribution of SAR in Groundwater samples (in year 2016)

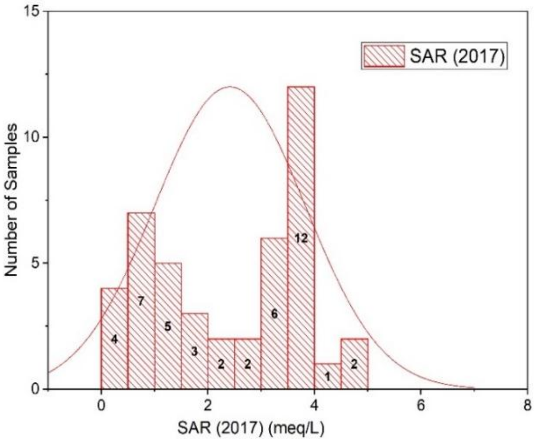


Fig. 5.3.2 Empirical probability distribution of SAR in Groundwater samples (in year 2017)

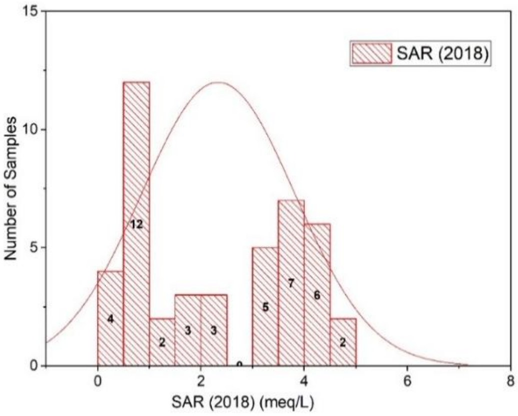


Fig. 5.3.3 Empirical probability distribution of SAR in Groundwater samples (in year 2018)

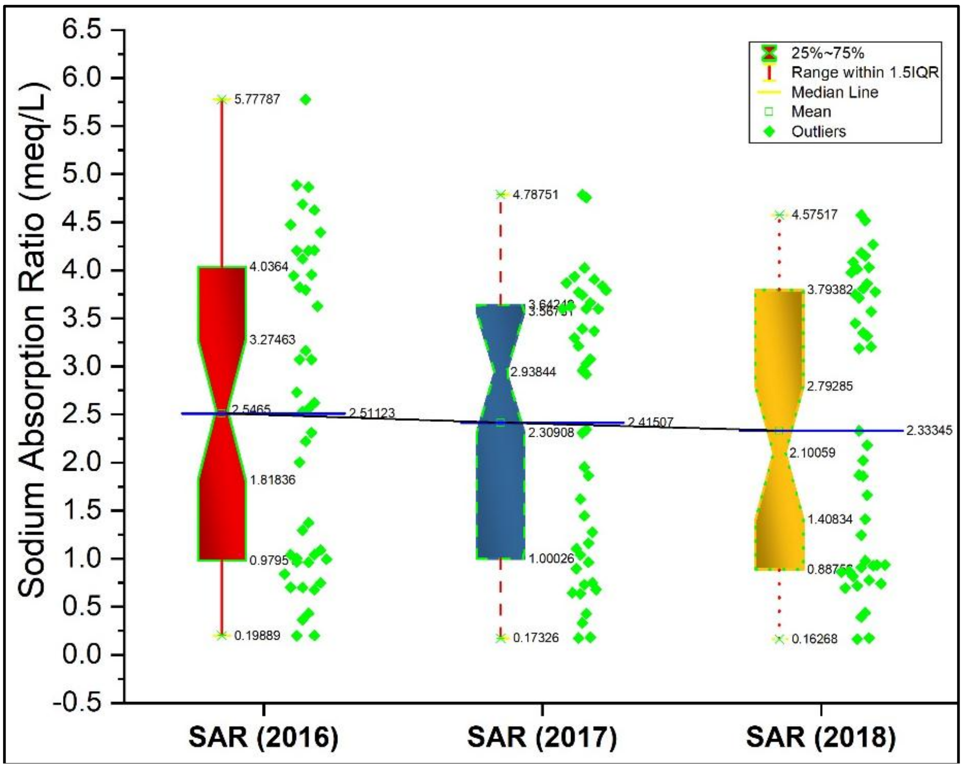


Fig. 5.3.4 Box and Whisker plot of SAR in Groundwater samples during study period (2016-2018)

5.3.2.3 Residual Sodium Carbonate (RSC)

Eaton, (1950) has put forward the characteristic feature of residual sodium carbonate for irrigation quality of water. RSC considers the excess of carbonate and bicarbonate in comparison to calcium and magnesium. RSC can be calculated by using the formula-

RSC = (HCO_3 + CO_3) – (Ca + Mg)

Concentration of all ions were taken in meq/L. RSC value of analysed underground water samples during study period is given in Table – 5.3.5. In year 2016, RSC value of analysed samples varied from -10.76 to 2.68 meq/L. The range of RSC in 2017 was from -6.92 to 2.52 meq/L and in 2018 it was from -7.63 to 2.45 meq/L. The positive value of RSC indicates the concentration of carbonate and bicarbonate is higher than calcium and magnesium. The high amount of carbonate and bicarbonate in irrigational water causes precipitation of calcium and magnesium ions. Due to precipitation of calcium and magnesium the water present in the soil becomes more concentrated in the form of sodium carbonate. According to Richards (1954) groundwater with RSC value < 1.25 meq/L is good for irrigation. Groundwater with RSC value between 1.25 and 2.50 meq/L is doubtful and can be used with proper drainage system. The groundwater samples having RSC value above 2.50 meq/L are not fit for irrigation. Nearly all the analysed samples (except one) were good for irrigation in terms of RSC value (Table – 5.3.6).

Throughout the study period, distribution curves for RSC value of analysed groundwater samples are given in Fig. 5.3.5, 5.3.6 & 5.3.7. During the study period, groundwater of Badhpura water quality station showed high value of RSC. Exceptionally high value of RSC in samples collected from Badhpura water quality station is also explained through box and whisker plot (Fig. 5.3.8). The use of such water is harmful for irrigation purpose, as they tend to precipitate calcium carbonate on the soil surface which result into permeability problem. Such water quality can be used for irrigation of specific crop with special soil management.

Table – 5.3.5 Residual Sodium Carbonate (RSC) of Groundwater Samples during study period

Water Quality Station	RSC (meq/L)					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	-3.84	-3.89	-1.54	-2.10	-4.59	-4.15
Duryai	-2.19	-2.14	-2.13	-2.09	-2.37	-2.20
Duryai	-1.79	-1.79	-0.51	-1.33	-2.04	-1.81
Talabpur	-3.33	-3.24	-3.03	-2.94	-4.86	-4.26
Bisrakh Road	-2.66	-2.50	-2.24	-2.24	-2.58	-2.35
Bisrakh Road	-7.03	-6.64	-6.48	-6.18	-7.63	-6.29
Bisrakh Road	-6.60	-6.28	-5.57	-5.45	-5.95	-5.46
Bisrakh Road	-2.88	-2.95	-2.71	-2.71	-3.10	-2.82
Bisrakh Road	-3.04	-3.02	-2.50	-2.75	-3.46	-3.07
Khera Dharampura	-4.61	-4.23	-4.33	-3.90	-5.22	-4.64
Bishnuli	-0.09	-0.28	0.81	0.63	-1.15	-1.42
Achheja	-10.76	-10.29	-6.33	-6.28	-6.97	-6.88
Achheja	-3.53	-3.32	-3.15	-2.98	-4.15	-3.71
Dujana	-2.60	-2.38	-1.64	-1.80	-3.45	-3.50
Dujana	-7.70	-6.79	-6.92	-6.19	-6.45	-5.61
Dujana	-4.54	-4.29	-4.57	-4.12	-5.49	-4.66
Dujana	-5.24	-5.10	-5.63	-5.43	-5.83	-4.43
Badalpur	-5.90	-5.16	-6.38	-5.75	-6.76	-5.09
Sadopur	-3.44	-3.39	-2.66	-2.39	-2.85	-2.78
Dairy Maccha	-1.41	-1.40	-1.60	-1.54	-1.83	-1.95
Dhoom Manikpur	-0.54	-1.26	0.05	0.10	0.29	-0.65
Badhpura	2.56	2.68	2.52	1.77	2.45	1.67
Minimum	-10.76	-10.29	-6.92	-6.28	-7.63	-6.88
Maximum	2.56	2.68	2.5	1.8	2.45	1.67
Mean	-3.7	-3.5	-3.02	-3.0	-3.82	-3.46

Table – 5.3.6 Classification of studied groundwater samples based on Residual Sodium Carbonate

RSC (meq/L)	Water Class	Percentage of samples					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<1.25	Good	95.5%	95.5%	95.5%	95.5%	95.5%	95.5%
1.25-2.50	Medium	-	-	-	4.5%	4.5%	4.5%
>2.50	Bad	4.5%	4.5%	4.5%	-	-	-

Salifu et al., (2017) reported that 56% of groundwater samples of Wa-Lawra Gold belt in Ghana was safe for irrigation in terms of RSC value. Madhav et al., (2018) analysed the irrigation suitability of groundwater of Sant Ravidas Nagar (Bhadohi) in Uttar Pradesh. They concluded that 100% of examined samples are in the safe class of RSC i.e. less than 1.25meq/L. Various studies have been carried out to assess the suitability of groundwater for irrigation in China (Peiyue et al., 2011; Wang, 2013; Wu & Sun, 2016), Bangladesh (Islam et al., 2016), Nigeria (Ishaku et al., 2011; Akakuru & Akudinobi, 2018), Japan (Mitra et al., 2007), Iran (Aghazadeh & Mogaddam, 2010; Soleimani et al., 2018) and in other parts of the world (Al-Obaidi, 2017; Ahada & Suthar, 2018).

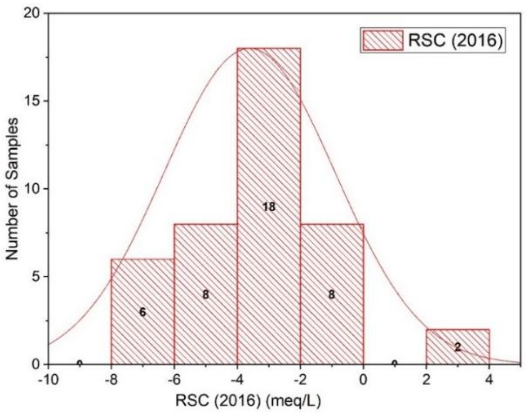


Fig. 5.3.5 Empirical probability distribution of RSC in Groundwater samples (in year 2016)

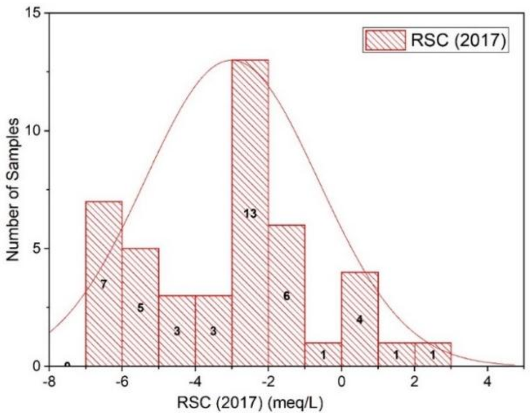


Fig. 5.3.6 Empirical probability distribution of RSC in Groundwater samples (in year 2017)

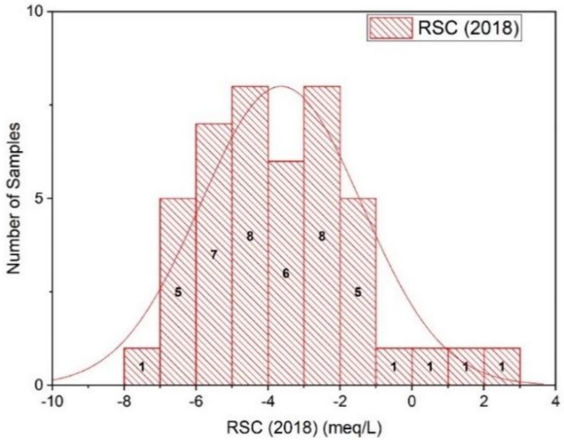


Fig. 5.3.7 Empirical probability distribution of RSC in Groundwater samples (in year 2018)

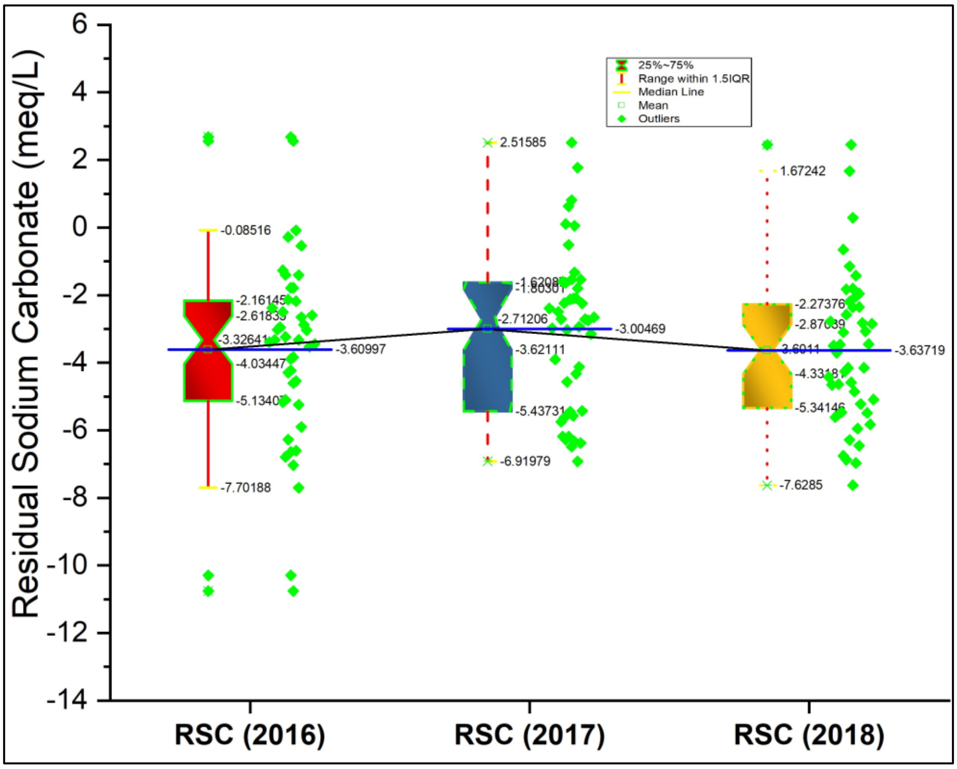


Fig. 5.3.8 Box and Whisker plot of RSC in Groundwater samples during study period (2016-2018)

5.3.2.4 Sodium Percentage (Na%)

Sodium percentage is used for assessment of sodium hazard in water. Sodium percentage is a parameter to evaluate the suitability of water for irrigation. This is because sodium which is present in irrigation water reacts with soil and reduce its permeability (Salifu et al., 2017). The mathematical exepression used for the calculation of sodium percentage is-

$$Na\% = \frac{Na+K}{Ca+Mg+Na+K} \times 100$$

Concentration of all the cations were taken in meq/L. Na% value of analysed groundwater samples during study period is given in Table – 5.3.7. The Na% of groundwater samples ranged from 6.94% to 62.68%. The standard sodium percentage of safe water for irrigation is 60% (Fipps, 2003). When irrigational water has high sodium percentage, sodium ions undergone cation exchange process with calcium and magnesium ions of soil hence reduces the permeability of soil (Saleh et al., 2017). The soil becomes alkaline (due to the formation of Na_2CO_3) and saline (due to the formation of NaCl) (Janardhana Raju, 2007). Highly alkaline and saline soil is not good for crop. The classification of studied samples on the basis of sodium percentage (Wilcox, 1955) is given in Table – 5.3.8.

Table – 5.3.7 Sodium Percentage (Na%) of Groundwater Samples during study period

Water Quality Station	Na%					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	38.19	36.43	48.62	39.71	35.64	35.16
Duryai	29.92	29.64	33.32	31.34	29.99	28.60
Duryai	26.11	25.23	39.44	27.38	24.89	24.97
Talabpur	20.90	20.57	22.04	21.21	21.12	21.08
Bisrakh Road	26.56	26.24	29.99	29.24	26.24	25.29
Bisrakh Road	41.56	41.58	41.61	41.36	41.50	42.02
Bisrakh Road	38.36	38.59	38.36	38.54	38.17	38.09
Bisrakh Road	27.51	26.74	29.14	26.49	25.65	25.80
Bisrakh Road	23.90	23.06	24.83	21.82	21.61	21.63
Khera Dharampura	20.21	18.65	15.29	16.64	19.16	19.14
Bishnuli	48.26	44.72	54.29	52.91	36.81	35.35
Achheja	45.22	44.89	45.27	44.91	44.73	44.44
Achheja	50.58	50.59	50.80	50.30	50.41	50.15
Dujana	14.14	13.17	15.14	12.90	12.94	12.47
Dujana	44.66	46.05	42.15	44.20	45.84	46.29
Dujana	45.87	46.24	45.49	46.72	46.78	46.64
Dujana	51.95	52.23	48.24	48.83	50.09	51.74
Badalpur	51.41	52.49	47.94	48.70	48.83	48.85
Sadopur	7.22	7.23	7.21	7.05	7.02	6.94
Dairy Maccha	62.68	57.05	53.29	52.25	51.90	49.60
Dhoom Manikpur	41.07	37.82	43.49	44.80	43.99	44.00
Badhpura	58.08	56.28	58.34	58.68	54.05	50.72
Minimum	7.22	7.23	7.21	7.05	7.02	6.94
Maximum	62.68	57.05	58.3	58.7	54.05	51.74
Mean	37.0	36.2	37.92	36.6	35.34	34.95

Table – 5.3.8 Classification of studied groundwater samples based on Sodium percentage

Na%	Water Class	Percentage of samples					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
20	Very Good	9.1%	13.6%	13.6%	13.6%	13.6%	13.6%
20-40	Good	40.9%	40.9%	31.8%	36.4%	40.9%	40.9%
40-60	Marginal	45.5%	45.5%	54.5%	50%	45.5%	45.5%
60-80	Poor	4.5%	-	-	-	-	-
>80	Unsuitable	-	-	-	-	-	-

From the Table – 5.3.7 & 5.3.8, it is observed that in pre-monsoon season of year 2016, 9.1% of samples belong to very good type, 41% of samples belong to good type, 45.5% of samples belong to marginal type and 4.5% fall under the category of poor type. Analytical results of study revealed that one sample collected from Dairy Maccha water quality station in pre-monsoon season of year 2016 had poor quality of water in terms of irrigation. In post-monsoon samples of year 2016, quality of water had improved and none of the sample showed poor quality of water. In pre-monsoon sample of year 2017, 54.5% of the collected samples have marginal type of water, 31.8% have good quality of water and 13.6% of samples (Khera Dharampura, Dujana and Sadopur stations) have very good quality of water. In post-monsoon samples of year 2017, percentage of samples having good water quality increased from 31.8% to 36.4% and percentage of samples having marginal water quality decreased from 54.5% to 50%. In year 2018, analysed samples belong to three classes (45.5% samples have marginal type water, 40.9% samples have good water and 13.6% have very good type of water in terms of sodium percentage). The groundwater samples taken from Bisrakh Road, Bishnuli, Achheja, Dujana, Badalpur, Dairy Maccha, Dhoom Manikpur, Badhpura water quality stations have Na% between 40 to 60%. The results revealed that groundwater of these sites is not fit for irrigation but in the absence of alternative source of irrigation, it can be used with proper crop selection and proper drainage.

The empirical probability distribution plots of sodium percentage in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) are given in Fig. 5.3.9, 5.3.10 & 5.3.11 respectively. From the distribution plot, it is clear that majority of samples have Na% between 40 and 60. Box and whisker plot of

Na% value of groundwater samples is presented in Fig. 5.3.12. Data is symmetrically distributed in the range and no exceptional value was obtained.

The suitability of groundwater in Malwa region of Punjab was studied by Ahada & Suthar, (2018). They found that western part of study area has high sodium percentage (13.9% unsuitable) than that of eastern part (7.5% unsuitable). Panaskar et al., 2016 studied groundwater suitability for irrigation in Nanded Tehsil of Maharashtra and they found that most of the analysed samples (46%) comes in good category, 22% of samples have 40 to 60 Na%, 22% of samples have 60 to 80 Na%, 8% of samples have excellent type of water and 2% of samples were unsuitable type of water. A study made by Keesari et al., 2016 in Pondicherry area of south India revealed the geological as well as anthropogenic source of sodium in groundwater.

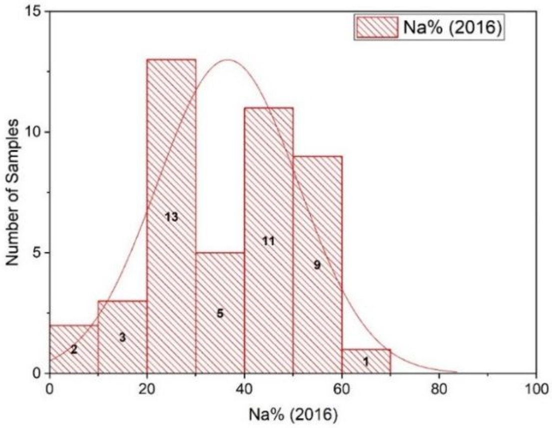


Fig. 5.3.9 Empirical probability distribution of Na% in Groundwater samples (in year 2016)

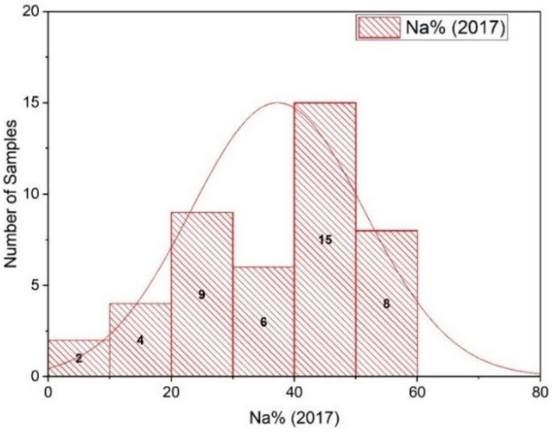


Fig. 5.3.10 Empirical probability distribution of Na% in Groundwater samples (in year 2017)

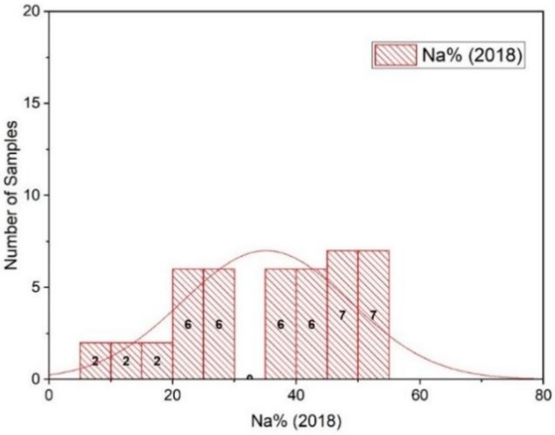


Fig. 5.3.11 Empirical probability distribution of Na% in Groundwater samples (in year 2018)

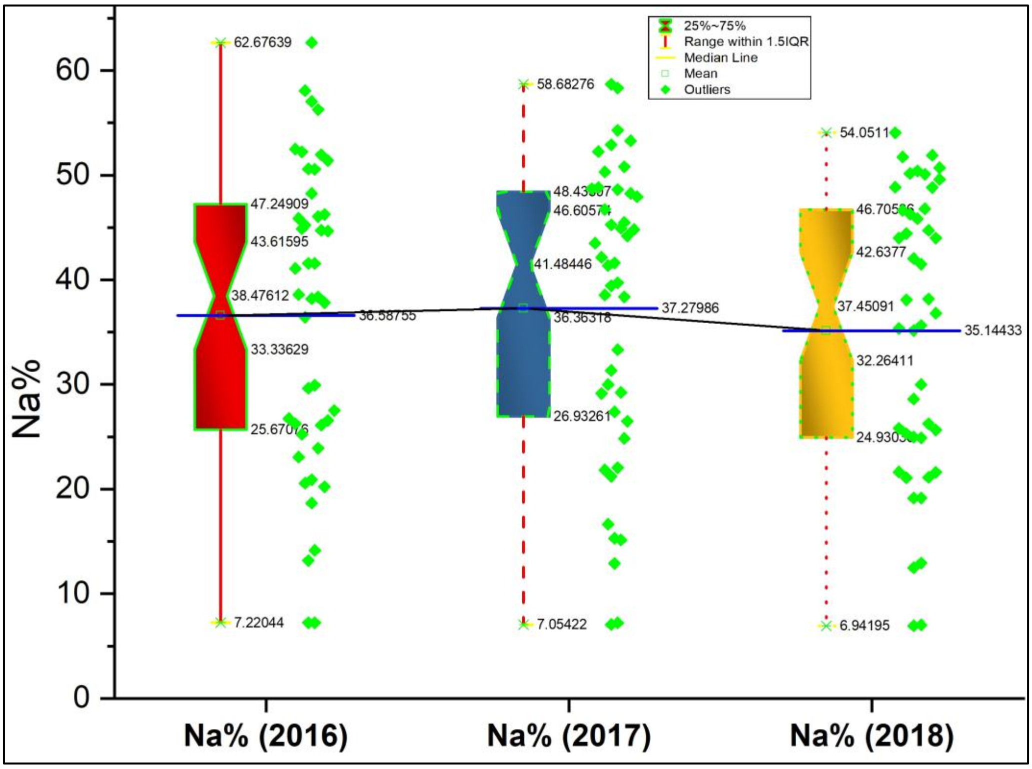


Fig. 5.3.12 Box and Whisker plot of Na% in Groundwater samples during study period (2016-2018)

5.3.2.5 Permeability Index (PI)

Permeability of soil is influenced by the sodium, calcium, magnesium and bicarbonate content in irrigational water. A classification for suitability of groundwater on the basis of permeability index was developed by Doneen, (1964) & Ragunath, (1987). Permeability index (PI) is defined as-

$$\text{PI} = \frac{Na + \sqrt[2]{HCO3}}{Ca+Mg+Na} \times 100$$

Concentrations of all the ions were taken into meq/L. During study period, permeability index of analysed samples is given in Table – 5.3.9. Permeability index of analysed groundwater sample ranged from 30.71% (in pre-monsoon sample of 2016 from Sadopur water quality station) to 77.35% (in pre-monsoon sample of 2016 Dairy Maccha water quality station). A slight decrease in mean permeability value was observed in post-monsoon samples of year 2016 and 2017. However permeability index increased in post-monsoon season of year 2018.

Doneen (1964) classify the water into three classes. Class 1 having permeability index greater than 75% is suitable for irrigation. Class 2 with permeability index 25 to 75%

is also good for irrigation. But class 3 with permeability index less than 25% is unsuitable for irrigation (Table – 5.3.10). On the basis of analytical results majority of the analysed samples (95%) fell under the class 2 & remaining 5% came under the class 1. Groundwater samples collected from Dairy Maccha (in pre-monsoon season of year 2016) and Bishnuli (in pre and post- monsoon season of year 2017) water quality station showed class 1 type of irrigation water in terms of permeability index. The results indicate that groundwater of current study area has class 2 type of quality of water with permeability index value 25% to 75%.

Table – 5.3.9 Permeability Index (PI) of Groundwater Samples during study period

Water Quality Station	PI (%)					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	52.18	50.62	66.44	58.20	48.55	48.89
Duryai	51.55	51.71	54.45	53.35	51.11	51.15
Duryai	49.84	49.65	65.25	53.24	47.79	49.34
Talabpur	39.06	39.19	41.07	40.30	34.38	35.58
Bisrakh Road	47.60	48.13	52.28	51.69	47.09	47.31
Bisrakh Road	50.35	50.65	50.83	51.00	49.95	51.57
Bisrakh Road	46.27	46.77	47.26	47.48	46.47	46.73
Bisrakh Road	46.35	45.51	49.41	46.04	43.55	44.42
Bisrakh Road	41.75	41.20	47.13	43.49	39.48	40.69
Khera Dharampura	37.28	36.84	34.11	36.16	35.17	36.09
Bishnuli	68.47	66.14	76.18	75.14	57.23	56.09
Achheja	51.94	51.84	54.63	54.38	53.58	53.36
Achheja	61.37	61.78	62.27	62.34	60.62	61.12
Dujana	38.20	38.68	45.54	43.21	33.96	33.48
Dujana	51.40	53.29	49.51	52.04	53.55	54.76
Dujana	54.77	55.36	54.38	56.00	54.56	55.30
Dujana	59.23	59.64	55.41	56.14	57.00	60.10
Badalpur	58.66	60.47	55.05	56.42	55.82	57.40
Sadopur	30.71	30.90	34.22	35.70	33.07	33.29
Dairy Maccha	77.35	74.26	69.33	68.88	67.42	65.90
Dhoom Manikpur	60.05	57.12	60.36	62.83	60.80	61.21
Badhpura	70.38	70.91	74.48	73.99	68.46	66.41
Minimum	30.71	30.90	34.11	35.70	33.07	33.29
Maximum	77.35	74.26	76.2	75.1	68.46	66.41
Mean	52.0	51.8	54.53	53.5	49.98	50.46

The empirical probability distribution plot of PI in groundwater samples collected from study area during three consecutive year (2016, 2017 & 2018) is given in Fig. 5.3.13, 5.3.14 & 5.3.15. Most of the samples have PI ranged from 45% to 55%. Box-whisker plot reflects that mean value is very close to median value (fig. 5.3.16). Salifu et al., 2017 analysed class 1 type of water (permeability index > 75%) in upper west region of Ghana. Soleimani et al., 2018 reported that all the analysed samples were of class 2 type in terms of permeability index in Sarpol-e Zahab city of Kermanshah province, Iran.

Table – 5.3.10 Classification of studied groundwater samples based on Permeability Index

PI (%)	Water Class	Percentage of samples					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
>75%	Class 1	4.5%	-	4.5%	4.5%	-	-
25% - 75%	Class 2	95.5%	100%	95.5%	95.5%	100%	100%
<25%	Class 3	-	-	-	-	-	-

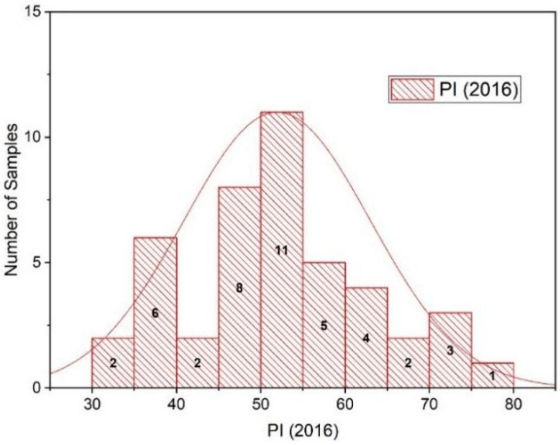


Fig. 5.3.13 Empirical probability distribution of Permeability Index in Groundwater samples (in year 2016)

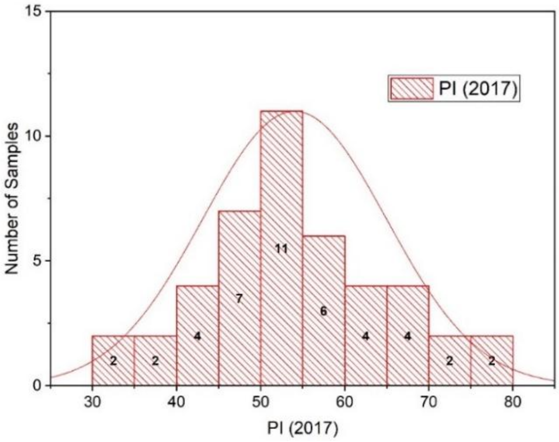


Fig. 5.3.14 Empirical probability distribution of Permeability Index in Groundwater samples (in year 2017)

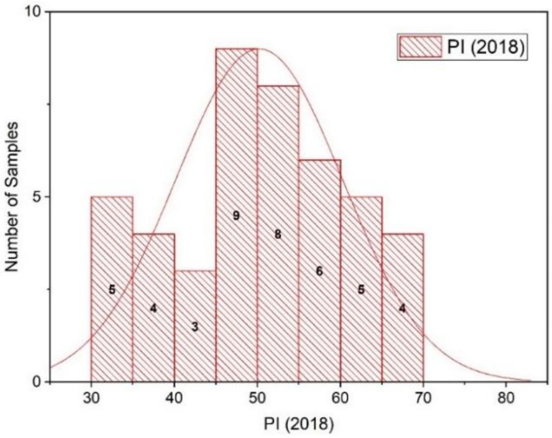


Fig. 5.3.15 Empirical probability distribution of Permeability Index in Groundwater samples (in year 2018)

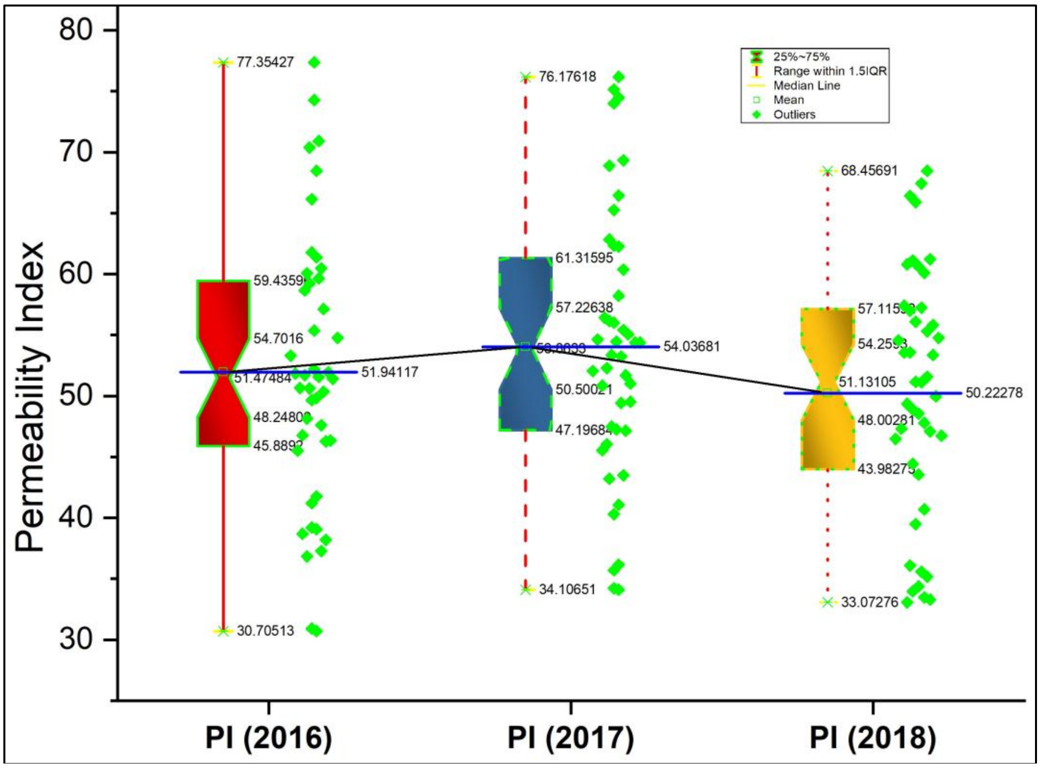


Fig. 5.3.16 Box and Whisker plot of PI in Groundwater samples during study period (2016-2018)

5.3.2.6 Magnesium Hazard (MH)

In natural conditions, calcium and magnesium remains in equilibrium in subsurface water. High level of magnesium negatively affects the soil productivity and overall crop yield (Kaka et al., 2011). High concentration of magnesium enhances the alkalinity of soil. High magnesium deteriorates the soil structure particularly when excess of sodium is present in irrigational water. Paliwal, (1972) introduced magnesium hazard value for irrigational water as-

$$\text{MH} = \frac{Mg}{Ca+Mg} \times 100$$

All concentrations were taken in meq/L. Magnesium hazard value of analysed groundwater samples during study period is given in Table – 5.3.11. Magnesium hazard ranged from 36.20% (at Dujana water quality station in pre-monsoon sample of year 2016) to 93.46% (at Dhoom Manikpur water quality station in pre-monsoon season of year 2017). Throughout study period, mean value of magnesium hazard was higher than 50%.

Table – 5.3.11 Magnesium Hazard (MH) of Groundwater Samples during study period

Water Quality Station	Magnesium Hazard (%) of Groundwater Samples					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	73.90	75.04	68.97	67.22	75.66	76.15
Duryai	79.93	80.22	79.25	79.58	79.88	80.49
Duryai	71.01	71.06	73.52	64.29	72.40	72.81
Talabpur	83.55	83.46	83.55	83.62	83.92	84.03
Bisrakh Road	69.03	68.06	72.56	72.83	74.37	75.07
Bisrakh Road	40.21	40.53	39.93	39.85	39.80	39.42
Bisrakh Road	85.28	85.18	85.36	85.25	84.31	84.83
Bisrakh Road	81.20	81.58	81.12	81.86	82.36	82.73
Bisrakh Road	74.79	74.36	74.89	74.99	77.28	77.45
Khera Dharampura	90.15	89.78	90.52	90.47	90.69	90.32
Bishnuli	85.99	85.73	84.08	84.47	82.71	82.85
Achheja	46.97	47.23	46.91	47.28	47.60	47.95
Achheja	43.09	42.83	42.62	43.20	42.93	42.85
Dujana	65.57	65.32	62.90	63.26	63.79	66.22
Dujana	43.03	42.67	45.33	45.27	44.04	43.99
Dujana	47.87	47.47	47.88	48.28	48.39	48.81
Dujana	36.20	36.26	38.31	38.37	38.31	38.43
Badalpur	39.21	38.71	40.44	40.10	39.71	39.48
Sadopur	86.61	86.53	86.23	85.52	86.34	86.98
Dairy Maccha	87.95	83.41	87.30	87.18	87.46	88.18
Dhoom Manikpur	88.86	89.53	93.46	93.42	93.31	93.26
Badhpura	40.28	42.47	41.64	44.59	42.89	37.02
Minimum	36.20	36.26	38.31	38.37	38.31	37.02
Maximum	90.15	89.78	93.46	93.40	93.31	93.26
Mean	66.40	66.20	66.67	66.40	67.19	67.24

According to categorization of Paliwal (1972), water with magnesium hazard value less than 50 is suitable for agriculture and magnesium hazard value greater than 50 is unsuitable for agriculture. In current analysis 63.6% of groundwater samples had magnesium hazard value above 50 hence these samples were harmful for crop yield. Around 36.4% of samples had magnesium hazard value less than 50 hence good for agriculture (Table – 5.3.12). One sample of Bisrakh Road station, Achheja, Dujana, Badalpur and Badhpura have MH less than 50.

Probability distribution curve of MH percentage in all analysed samples are presented in Fig. 5.3.17, 5.3.18 & 5.3.19 (for year 2016, 2017 & 2018). Quantile plot was also drawn to summarize the magnesium hazard data obtained from analysis (Fig. 5.3.20).

Narsimha et al., (2013) analysed magnesium hazard value of groundwater samples in Hanmakonda Area, Warangal District of Andhra Pradesh and reported that 89% of samples were suitable for irrigation.

Table – 5.3.12 Classification of studied groundwater samples based on Magnesium Hazard

MH (%)	Water Class	Percentage of samples					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<50%	Suitable	36.4%	36.4%	36.4%	36.4%	36.4%	36.4%
>50%	Unsuitable	63.6%	63.6%	63.6%	63.6%	63.6%	63.6%

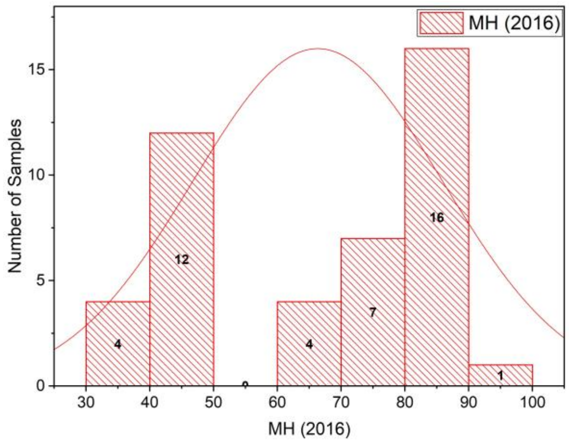


Fig. 5.3.17 Empirical probability distribution of MH in Groundwater samples (in year 2016)

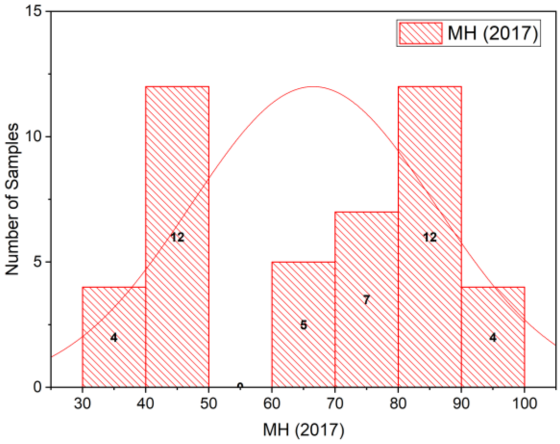


Fig. 5.3.18 Empirical probability distribution of MH in Groundwater samples (in year 2017)

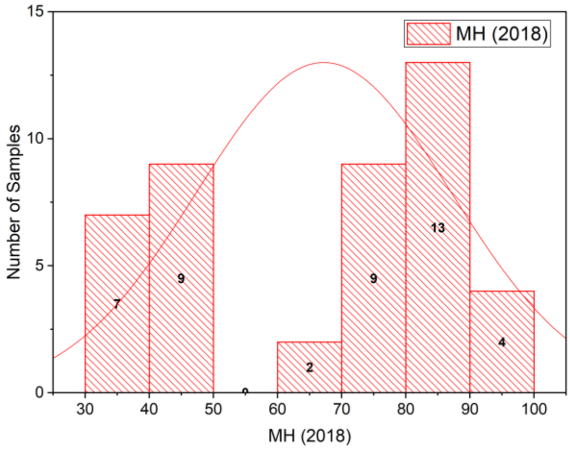


Fig. 5.3.19 Empirical probability distribution of MH in Groundwater samples (in year 2018)

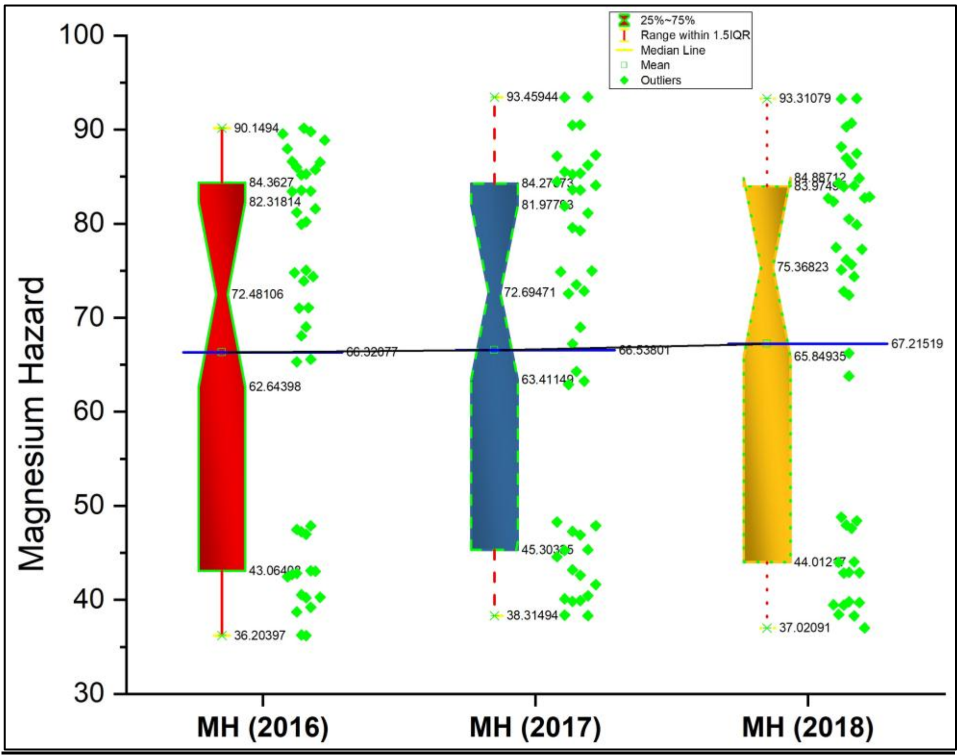


Fig. 5.3.20 Box and Whisker plot of MH in Groundwater samples during study period (2016-2018)

5.3.2.7 Kelly Index (KI)

Similar to sodium absorption ratio, kelly index is used to evaluate the relative concentration of sodium, calcium and magnesium in irrigational water (Gaikwad et al., 2019). Based on sodium content, kelly index is used to assess the fitness of underground water for irrigation purposes. Mathematical equation used for calculation of kelly index -

$$\text{KI} = \frac{Na}{Ca+Mg}$$

All concentrations were taken in meq/L. According to classification given by Kelly, (1940; 1951) water having kelly index value greater than one is unsuitable for irrigation and water with kelly index value less than one is suitable for irrigation. Kelly index value of analysed groundwater samples ranged from 0.050 to 1.637 meq/L (Table – 5.3.13). Higher values of KI were obtained from Achheja, Dairy Maccha and Badhpura stations. In 2016, around 91% of groundwater samples have KI value less than 1 and rest 9% of samples have KI value greater than 1. In 2017, 86.4% of samples were suitable (KI < 1) and 13.6% were unsuitable (KI > 1). In pre-monsoon season of 2018, 90.9% samples were suitable and 9.1% were unsuitable for irrigation but in post-monsoon season, 100% samples were fit for irrigation (Table – 5.3.14).

Distribution plot of KI value of groundwater samples showed that most of the samples were located on left side of plot in the range of 0 to 1 (Fig. 5.3.21, 5.3.22 & 5.3.23). From the analysis of box and whiskers plot, it is clear that data was symmetrical and only one outlier was present in year 2016 (Fig. 5.3.24).

Table – 5.3.13 Kelly Index (KI) of Groundwater Samples during study period

Water Quality Station	Kelly Index (meq/L) of Groundwater Samples					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	0.557	0.512	0.892	0.590	0.491	0.479
Duryai	0.394	0.384	0.472	0.429	0.400	0.372
Duryai	0.305	0.290	0.614	0.325	0.281	0.279
Talabpur	0.191	0.188	0.210	0.186	0.178	0.176
Bisrakh Road	0.329	0.323	0.396	0.381	0.307	0.286
Bisrakh Road	0.638	0.637	0.639	0.634	0.639	0.654
Bisrakh Road	0.536	0.541	0.536	0.538	0.526	0.520
Bisrakh Road	0.315	0.301	0.377	0.291	0.268	0.264
Bisrakh Road	0.231	0.219	0.295	0.244	0.223	0.223
Khera Dharampura	0.224	0.199	0.153	0.170	0.205	0.202
Bishnuli	0.886	0.765	1.150	1.086	0.513	0.473
Achheja	0.764	0.754	0.767	0.755	0.747	0.737
Achheja	0.933	0.935	0.941	0.920	0.926	0.914
Dujana	0.123	0.109	0.144	0.113	0.110	0.102
Dujana	0.704	0.750	0.628	0.692	0.748	0.764
Dujana	0.763	0.775	0.749	0.790	0.793	0.790
Dujana	0.954	0.967	0.806	0.828	0.878	0.949
Badalpur	0.942	0.993	0.806	0.836	0.845	0.845
Sadopur	0.054	0.054	0.055	0.054	0.052	0.050
Dairy Maccha	1.637	1.307	1.110	1.065	1.048	0.952
Dhoom Manikpur	0.667	0.577	0.739	0.782	0.752	0.753
Badhpura	1.238	1.144	1.242	1.255	1.035	0.934
Minimum	0.054	0.054	0.055	0.054	0.052	0.050
Maximum	1.637	1.307	1.242	1.255	1.048	0.952
Mean	0.608	0.578	0.624	0.589	0.544	0.533

Arslan, (2017) studied groundwater irrigation quality on the coastal aquifer of Çarşamba Plain, Turkey, from 1990 to 2012 and concluded that kelly index of groundwater is less than 1 in 1990. But in year 2012, 5.75% of the study area faced the problem of high sodium content in irrigation water. In Malwa region of Punjab, only 35% samples in eastern and 22.3% samples in western Malwa are suitable for irrigation in terms of kelly index (Ahada & Suthar, 2018).

Table – 5.3.14 Classification of studied groundwater samples based on Kelly Index

KI (meq/L)	Water Class	Percentage of samples					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
<1	Suitable	90.9%	90.9%	86.4%	86.4%	90.9%	100%
>1	Unsuitable	9.1%	9.1%	13.6%	13.6%	9.1%	-

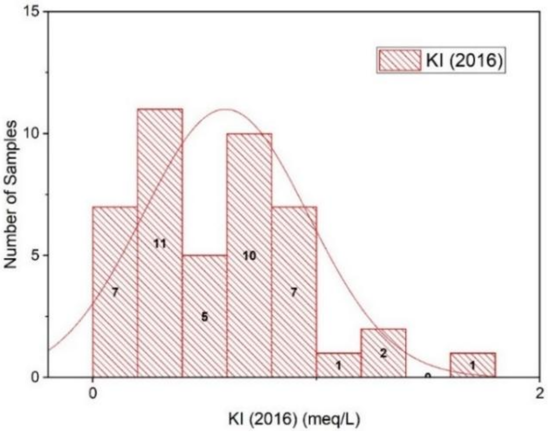


Fig. 5.3.21 Empirical probability distribution of KI in Groundwater samples (in year 2016)

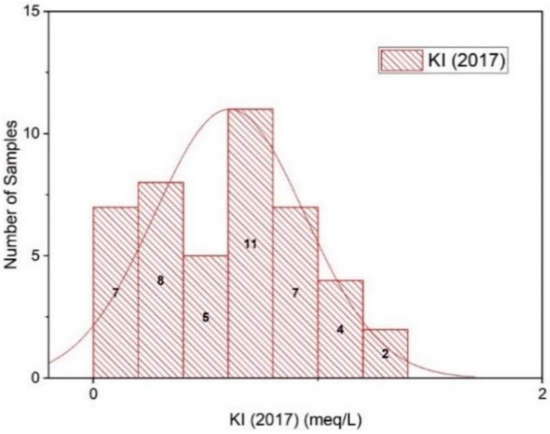


Fig. 5.3.22 Empirical probability distribution of KI in Groundwater samples (in year 2017)

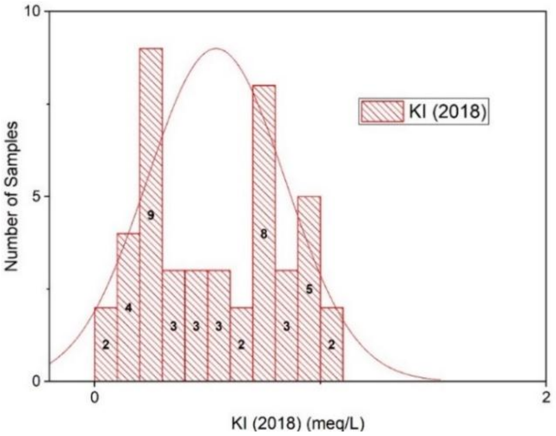


Fig. 5.3.23 Empirical probability distribution of KI in Groundwater samples (in year 2018)

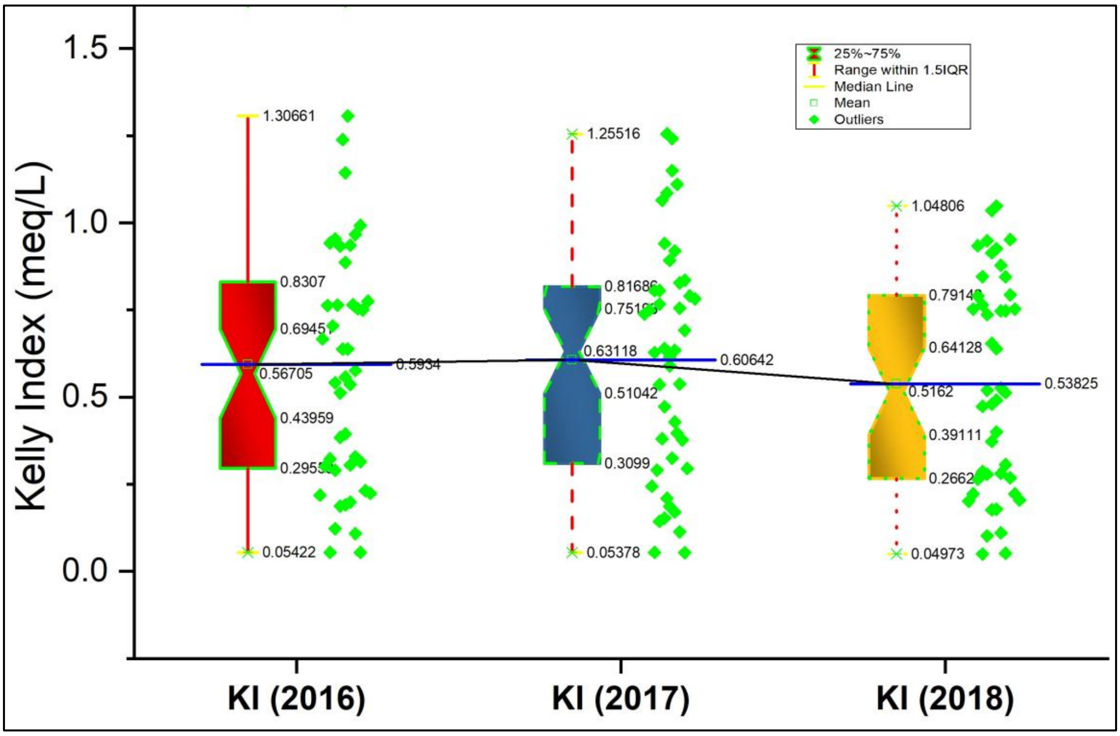


Fig. 5.3.24 Box and Whisker plot of KI in Groundwater samples during study period (2016-2018)

5.3.2.8 Boron Toxicity

Salt tolerance of various agricultural crops is different. High salt tolerance crops have special methods for managing high amount of salts. These type of crops can grow well in highly saline water. Many crops are highly sensitive to salt concentration of irrigation water. Sometimes even the lesser amount of salts in irrigation water, crops do not grow well due to boron sensitivity. Boron is essential for crops in low amounts, but toxic at higher concentrations. It causes burning and browning of the leaf top followed by yellowing of the margin. Many plants are very sensitive for boron toxicity. In fact, toxicity can occur on sensitive crops at concentrations less than 1.0 mg/L (Table – 5.3.15) (McFarland, et al., 2002; Bauder et al., 2017).

Boron content of analysed groundwater samples ranged from 0.19 to 3.14 mg/L (Table – 5.3.16). Boron concentration higher than 1 was obtained from Duryai, Talabpur, Bisrakh Road, Khera Dharampura, Achheja, Dujana and Badalpur water quality station. These stations were under the agricultural and industrial zone of study area. Groundwater of residential zone showed comparative lesser amount of boron. The results of study indicate leaching of agricultural water and industrial water were responsible for elevated concentration of boron in groundwater.

Table – 5.3.15 Critical value for Boron in irrigation water for major crops

Critical value of Boron (mg/L)	Sensitivity of crops	Major Crops
0.5-0.75	Highly Sensitive	Peach, Onion, Peanuts
0.76-1	Sensitive	Wheat, Barley, Sunflower, Dry Bean
1.1-2	Moderately Sensitive	Carrot, Potato, Cucumber
2.1-4	Moderately Tolerant	Lettuce, Cabbage, Corn, Oats, Cotton
4.1-6	Tolerant	Alfalfa, Sugarbeet, Tomato

Table – 5.3.16 Boron Toxicity of Groundwater Samples during study period

Water Quality Station	Boron (in mg/L) of Groundwater Samples					
	2016		2017		2018	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Duryai	3.14	2.94	1.98	1.75	2.08	1.90
Duryai	1.83	2.16	1.56	2.61	2.10	1.86
Duryai	1.02	0.93	0.83	0.97	1.07	0.93
Talabpur	2.67	2.13	2.69	1.91	2.41	2.12
Bisrakh Road	1.08	1.04	0.93	0.91	0.84	0.83
Bisrakh Road	0.47	0.39	0.61	0.72	0.64	0.59
Bisrakh Road	1.34	1.21	1.79	1.14	1.46	1.19
Bisrakh Road	1.03	1.05	1.46	1.20	1.58	1.43
Bisrakh Road	0.89	0.79	1.10	1.12	1.15	1.07
Khera Dharampura	1.12	1.09	1.32	0.97	0.91	0.83
Bishnuli	0.88	0.84	0.81	0.78	0.87	0.76
Achheja	0.67	0.74	0.83	0.79	0.69	0.83
Achheja	0.65	0.76	0.93	0.87	1.08	0.89
Dujana	0.99	0.89	1.15	1.05	1.88	1.64
Dujana	0.88	0.80	0.99	0.81	1.05	1.00
Dujana	1.10	1.08	1.13	1.04	1.35	1.18
Dujana	0.86	0.78	0.91	0.88	1.05	0.90
Badalpur	1.17	1.07	0.87	0.86	0.91	0.90
Sadopur	0.32	0.30	0.34	0.34	0.31	0.31
Dairy Maccha	0.57	0.55	0.41	0.41	0.55	0.54
Dhoom Manikpur	0.21	0.191	0.22	0.21	0.31	0.30
Badhpura	0.32	0.52	0.45	0.26	0.35	0.31
Minimum	0.21	0.191	0.22	0.21	0.31	0.30
Maximum	3.14	2.94	2.69	2.61	2.41	2.12
Mean	1.06	1.01	1.06	0.98	1.12	1.01

SUMMARY

In terms of salinity of water samples, groundwater of Bisrakh Road, Achheja, Dujana, Badalpur and Badhpura was very highly saline and unsuitable for irrigation. Groundwater samples of Achheja water quality station in year 2016, were very saline having electrical conductivity value 4251 and 4061 µmhos/cm. SAR values for all analysed samples were well below 10 meq/L, hence suitable for irrigation. In reference to RSC value, most of the samples were good for irrigation. Only one sample of Badhpura water quality station was unsuitable for irrigation.

Na% of majority of analysed samples were 20 to 60% hence have good to marginal sodium hazard. Na% value of one sample of Dairy Maccha water quality station was 62.68% hence unsuitable for agriculture. Groundwater samples of Khera Dharampura, Dujana and Sadopur were having good quality.

Most of the samples showed PI value between 25% and 75% which is good for crop yield. Water samples of Dairy Maccha and Bishnuli were having suitable PI value. Nearly 63.6% of groundwater samples had magnesium hazard value greater than 50 and hence unsuitable for irrigation. Samples of Khera Dharampura had maximum value of MH. Groundwater samples of Bishnuli, Dairy Maccha and Badhpura station have Kelly index value greater than 1 and hence unsuitable for irrigation.

The results of the study revealed that irrigational water quality of residential zone was comparatively poorer than industrial and agricultural zone. However boron toxicity was found higher in samples collected from industrial zone of study area (Duryai, Talabpur, Bisrakh Road, Khera Dharampura, Achheja, Dujana and Badalpur).

5.4.1. INTRODUCTION

Water is an important aspect of life on earth and most of the civilizations bloomed around the places where potable water was present. Various activities performed by humans need clean and fresh water (Cheremisinoff, 1997). A specific quality of water is required for cultivation, human consumption, and to run industries. As long as the human population was small, communities were scattered and industries yet to appear, wastewater created no problem and it could be disposed safely in vast expanse of nature without creating any environment problem. However by the end of twentieth century the industrial development and fast urbanization created a problem of wastewater and its disposal. It was simply discharged in natural water bodies, which created a new problem of water pollution. Wastewater is defined as liquid wastes originated due to various man made activities. The characteristics of waste water generated in any area depends upon the land use pattern of that area (Youcai, 2018).

The impact of the agricultural, industrial and domestic wastewater on ground water quality was studied to get extent of ground water pollution. Waste water originated from an industrial area contains a large quantity of dissolved ions, heavy metals and hazardous substances. While waste water coming from residential area contains nitrogenous wastes, phosphate and dissolved organic matter.

To understand the effect of waste water on groundwater quality, one sample from agricultural zone, eight samples from industrial zone and four samples from residential zone of study area, were collected from various drains during pre-monsoon & post-monsoon season of year 2016, 2017 and 2018 (Table – 4.2). Physico-chemical parameters and eight heavy metals (As, Cd, Cr, Cu, Ni, Pb, Fe & Zn) were analysed in collected waste water samples. General characteristics of waste water originated from various land use patterns was also done.

- Agricultural waste water charcateristics,
- Industrial waste water charcateristics,
- Residential waste water charcateristics,

5.4.2 AGRICULTURAL WASTE WATER CHARCATERISTICS

The composition of wastewater depends upon its source. In agricultural area, the waste water is greatly affected by amount of rainfall, irrigation return flow, type of crops, quality/quantity of applied fertilizers & pesticides. Major factors which affect the characteristics of waste water in agricultural area are-

Extensive use of fertilizers: The application of nitrogen rich fertilizers is very popular to enhance the crop yield. The increased use of nitrogen rich fertilizers promotes the chances of nitrogen loss from the soil. Most of the time nitrate requirement of crop is much lesser than the quantity of fertilizers added to it, as a result excess of NO_3-N accumulate in the soil (Schepers et al., 1991). Most commonly used fertilizers are- urea, ammonium nitrate, ammonium sulphate, calcium nitrate, di-ammonium phosphate, triple super phosphate, potassium nitrate, potassium chloride etc. Nitrogenous fertilizers when applied to soil it readily converts into nitrate. Nitrate compounds easily dissolve in water and hence readily leached with water. Introduction of these fertilizers to increase the crop production also increase nitrogen, phosphorus, potassium level in soil which ultimately washed away with rain water (Suthar et al., 2009).

Irrigation: Irrigation essentially means the watering of crop land to prepare it for agricultural activities. An irrigation system is defined as providing of water to growing plants and crops through artificial canals and channels. Besides the traditional methods of irrigation, currently drip irrigation & sprinkler irrigation method are widely used. These methods are water economically without wastage. Irrigation of crop through river/canal or groundwater adds a significant quantity of ions in the soil. The leaching of ions through soil is more prevalent in highly irrigated agricultural area. All the amount of added ions can’t be consumed by the crop and flush with irrigation return flow (Kundu & Mandal, 2009).

Waste water sample (L1) collected from village Talabpur was analysed to understand the effect of agricultural activities on waste water (Table – 4.2).

5.4.3 INDUSTRIAL WASTE WATER CHARCATERISTICS

Various kinds of liquid wastes generated through industries are termed as industrial wastewater. Characteristics of industrial wastewater in a region varies according to types of industries running in that region, process involved in industries, water requirement of the industry and type of wastes generated during manufacturing process. Seasonal fluctuations in the industrial wastewater discharges may also occur due to seasonal processing in various industries. In urbanized areas, industrial effluent contributes majorly in total waste water generated in area and plays crucial role in hydrological cycle. Various types of manufacturing units are running in villages of district Gautam Budh Nagar. Systematic sampling of waste water was done to analyze the characteristics of waste water of industrial area. Eight samples of waste water (L2-L9) were collected near from different manufacturing units (Table – 4.2). Sampling locations of waste water samples and nearby industries are given in Table – 5.4.1.

5.4.4 RESIDENTIAL WASTE WATER CHARCATERISTICS

India is a big country with more than 1.3 billion population hence the volume of domestic water is large. The treatment of domestic waste is not carried out in regular practice. Only metro and big cities have domestic and sewage treatment plants. According to census 2011, total population of Gautam Budh Nagar district is 16,48,115 with a population frequency of 1286 persons/Km^2. Population growth of district during 2001-2011 is 49.11%. The growth rates for rural and urban areas of the district are 1.63% and 120.29% respectively. This data reflects increasing urbanization in current study area. Generation of huge amount of waste water is a major problem in urbanized areas. Collection and proper disposal of domestic wastewater is a challenge in our society. Conventional methods are not sufficient for disposal of wastes. The quality of waste water is the resultant of domestic activities. Various activities which affects the characteristics of waste water of residential zone are; climate, habits of the people, unsewered sanitation, open land and stream discharge of sewage, sewage oxidation ponds, sewer leakage, solid waste disposal, landfills, road/urban run-off and aerial fall out. The major component of domestic waste water is urea [$CO(NH_2)$]. It is hydrolyzed to ammonia and carbon di-oxide by the enzyme urease present in sewage. Waste water originated from residential area is organic in nature. Various compounds of carbon, nitrogen and phosphorus are found in it. Ground water in several areas, where sewage is being discharged without proper treatment, has been adversely affected by contaminants associated with sewage (Abdalla & Khalil, 2018).

Table – 5.4.1 Sampling Stations of Waste water and Nearby Industries

Waste water Sample No.	Sampling Station	Nearby Industry	Products Manufactured
L1	Talabpur	SVS Wires Pvt. Ltd.	Polyethylene coated, nickel chrome, epoxy coated, stainless steel, nylon coated wire shelves, freezer baskets, dish washer racks, wire-on tube condenser etc.
L2	Bisrakh Road	Surya Processors Pvt. Ltd., Surya Textiles.	Dyeing, Weaving, Printing and Yarn-dyed fabrics.
L3	Bisrakh Road	Assomach Machines Ltd.	Wire drawing machinery.
L4	Bisrakh Road	Shri Balaji Garments Industries(P) Ltd.	Plastic injection molding, Industrial plastic buckets, Paint plastic buckets, Chemical plastic buckets, Chemical plastic jar, Engine oil Buckets, and Lubricant oil buckets.
L5	Bisrakh Road	Harsh Chemicals.	Industrial chemicals, Thinners, Solvents, Chemicals and Organic/ Inorganic Solvents.
L6	Bisrakh Road	Suchi Paper Mill.	Paper product.
L7	Khera Dharampura	JMD industry, KRBL Limited Rice mill.	Overhead water tanks (NIPCO), Basmati rice (India Gate, Doon, Nur Jahan, Indian Farm, Bemisal, Aarati etc.).
L8	Bishnuli	Garg Tube limilted.	Pipes and Tubes (ERW black steel pipe, Galvanized steel pipes).
L9	Achheja	CHW forge.	Forgings and Flanges.
L10	Dairy Maccha		
L11	Dhoom Manikpur	Deep Chand Arya Industries.	Nirma Bath soap.
L12	Dhoom Manikpur	Ambuja Cement.	Cement.
L13	Badhpura		

Domestic waste water of three villages was analysed to explain the effects of human activity on waste water discharge.

1. Dairy Maccha nallah (L10)
2. Dhoom Manikpur nallah (L11, L12)
3. Badhpura nallah (L13)

Results of physico-chemical and heavy metal analysis of collected waste water samples are presented under two sub-headings.

1. Physico-chemical Parameters
2. Heavy Metals

5.4.5 PHYSICO-CHEMICAL PARAMETERS

5.4.5.1 Hydrogen Ion Concentration (pH)

Hydrogen ion concentration (pH) of water is determined mainly by the equilibrium between the concentration of free carbon dioxide, bicarbonates and carbonates. pH value of water is affected by the presence of chemical and organic substances. Anthropogenic activities such as chemical spills, agricultural runoff, sewage effluents and soil leaching disturbs the natural pH of water.

Analytical results of pH of waste water samples during study period are presented in Table – 5.4.2. The range of pH in waste water samples under study was from 5.87 to 9.71 with a mean value of 7.63. Most of the collected samples have alkaline pH. Similar type of trend; neutral to alkaline (7.09 to 9.15) was obtained in groundwater samples of study area. A variation in pH value was observed in different zone of study area; 7.15 to 8.4 in agricultural zone, 5.89 to 9.71 in industrial zone and 5.87 to 8.65 in residential zone. A wide range of pH of waste water in industrial area indicates the presence of various types of chemicals in it. Fig. 5.4.1 explains the relation between pH of groundwater and waste water samples in three different zone of study area. Environment Protection rule, 1986 sets a range of pH (5.5 – 9) for inland surface water and public sewers (Table – 4.8). Three waste water samples collected from industrial zone (L3, L5 and L9) crossed the upper limit of pH in effluents. Alkaline nature of leachate coming from closed dumpsite was observed by Maitia et al., 2016 in Dhapa, Kolkata.

Table – 5.4.2 pH of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	8.4	7.67	7.39
			Post-monsoon	7.85	7.15	7.56
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	8.18	7.66	7.8
			Post-monsoon	8.1	8.05	7.15
	L3	Bisrakh Road	Pre-monsoon	7.62	8.62	9.13
			Post-monsoon	7.2	8.15	8.7
	L4	Bisrakh Road	Pre-monsoon	7.53	8.72	8.1
			Post-monsoon	7.86	7.79	8.08
	L5	Bisrakh Road	Pre-monsoon	9.28	9.31	8.35
			Post-monsoon	8.58	7.5	7.8
	L6	Bisrakh Road	Pre-monsoon	7.7	7.32	7.2
			Post-monsoon	7.54	8.12	7.1
	L7	Khera Dharampura	Pre-monsoon	5.89	6.81	7.12
			Post-monsoon	6.71	6.95	7.15
	L8	Bishnuli	Pre-monsoon	6.57	7.37	7.85
			Post-monsoon	6.61	7.12	7.3
	L9	Achheja	Pre-monsoon	9.71	8.43	7.46
			Post-monsoon	8.77	7.91	6.89
Residential Zone	L10	Dairy Maccha	Pre-monsoon	7.91	7.83	8.1
			Post-monsoon	7.44	7.81	7.91
	L11	Dhoom Manikpur	Pre-monsoon	6.33	7.8	7.22
			Post-monsoon	6.89	7.53	8.65
	L12	Dhoom Manikpur	Pre-monsoon	6.33	5.87	6.19
			Post-monsoon	6.85	6.21	6.15
	L13	Badhpura	Pre-monsoon	7.6	7.5	8.6
			Post-monsoon	7.89	7.65	7.9

5.4.5.2 Electrical Conductivity (EC)

Pure water has a very low electrical conductivity but effluents from industries, city wastages, mining operations, agricultural runoffs etc. have high conductivity values. The septic tank effluents having higher ionic concentrations contribute to high conductance value (Allhajjar et al., 1990).

Analytical results of electrical conductivity of waste water samples during study period are shown in Table – 5.4.3.

Table – 5.4.3 Electrical Conductivity (in µmhos/cm) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	1880	1654	2234
			Post-monsoon	1810	1835	2123
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	1265	1100	1650
			Post-monsoon	1230	1210	1510
	L3	Bisrakh Road	Pre-monsoon	3308	2650	4740
			Post-monsoon	3220	3885	4506
	L4	Bisrakh Road	Pre-monsoon	3680	2607	4500
			Post-monsoon	3603	3601	4085
	L5	Bisrakh Road	Pre-monsoon	5090	4354	5600
			Post-monsoon	4715	5148	4885
	L6	Bisrakh Road	Pre-monsoon	2250	1568	2000
			Post-monsoon	2167	1700	1880
	L7	Khera Dharampura	Pre-monsoon	3119	2604	3534
			Post-monsoon	3020	2540	3230
	L8	Bishnuli	Pre-monsoon	3878	2639	3856
			Post-monsoon	3713	3460	3668
	L9	Achheja	Pre-monsoon	4793	2670	4439
			Post-monsoon	4650	3770	4290
Residential Zone	L10	Dairy Maccha	Pre-monsoon	2665	2268	3045
			Post-monsoon	2587	2470	2782
	L11	Dhoom Manikpur	Pre-monsoon	1200	997	1613
			Post-monsoon	1130	1203	1560
	L12	Dhoom Manikpur	Pre-monsoon	2820	1628	2900
			Post-monsoon	2778	1990	2885
	L13	Badhpura	Pre-monsoon	4530	2201	4655
			Post-monsoon	4378	2550	4153

Electrical conductivity of agricultural waste water of study area ranged from 1654 to 2234 µmhos/cm. Electrical conductivity of waste water from all industries was found to be in the range of 1100 to 5600 µmho/cm giving a mean value 3283 µmhos/cm. The minimum electrical conductivity was recorded from the waste water sample taken from Bisrakh Road (L2) while maximum was recorded in sample L5. A chemical factory was present near to the source of sample L5, which contributed to high electrical conductance of waste water sample. Electrical conductivity of the effluent depends on the type of industry running. Electrical conductance of domestic waste water of study area was also very high (ranged from 997 to 4655 µmhos/cm). The electrical conductance of Dhoom Manikpur nallah was recorded minimum while the maximum was recorded from Badhpura nallah. Fig. 5.4.2 demonstrates the relation between conductance of groundwater and waste water samples in three different zone of study area. Kamble & Sharma, (2016) studied the impact of leachate originated from a dumpsite on groundwater quality in Jawaharnagar village of Telangana. Conductivity of leachate sample decreased from 55000 µmho/cm to 6450 µmho/cm after rainfall.

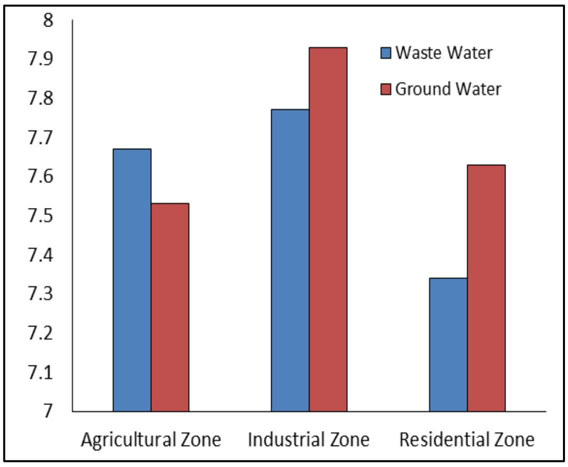


Fig. 5.4.1 Mean pH value of Waste water and Groundwater samples in different zone of study area

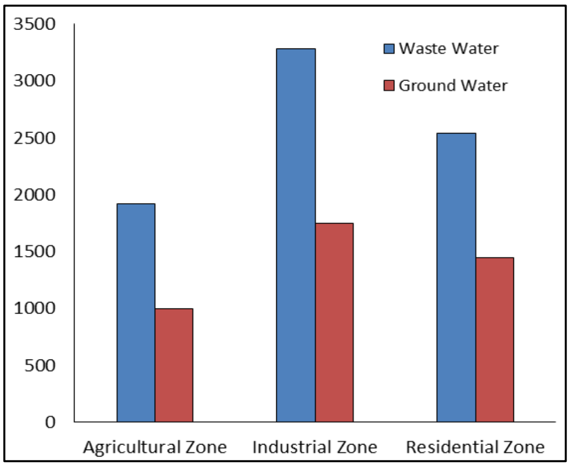


Fig. 5.4.2 Mean Electrical Conductivity of Waste water and Groundwater samples in different zone of study area

5.4.5.3 Total Dissolved Solids (TDS)

Total suspended solids in waste water mainly contain carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates and fluorides of Na, K, Ca, Mg and Mn along with organic matters, silts etc. It represents quantity of substances present in water other than suspended solids.

Analytical results of total dissolved solids of waste water samples during study period are presented in Table – 5.4.4. Total dissolved Solids of waste water of study area were recorded in a great variation. The minimum total dissolved Solids (648 mg/L) was recorded from Dhoom Manikpur nallah in pre-monsoon sample of year 2017 while maximum (3642 mg/L) was recorded from Bisrakh Road (L5) in pre-monsoon sample of year 2018. Total dissolved solids of analysed waste water samples in agricultural zone ranged from 1075 mg/L to 1451 mg/L. Total dissolved solids of industrial waste water were found to vary from 715 to 3642 mg/L. The minimum total dissolved solid was recorded from waste water sample L2 from Bisrakh Road while maximum recorded from waste water sample L5 from Bisrakh Road. TDS of domestic waste water was recorded minimum of 648 mg/L in Dhoom Manikpur nallah and maximum of 3027 mg/L in Badhpura Nallah. Fig. 5.4.3 describes the relation between mean value of TDS in groundwater and waste water samples in three different zone of study area. Olaoye & Oladeji, (2015) analysed characteristics of effluent of paint industry in Ibadan of Nigeria and reported TDS of 987 mg/L.

Table – 5.4.4 Total Dissolved Solids (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	1225	1075	1451
			Post-monsoon	1175	1194	1378
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	821	715	1074
			Post-monsoon	801	788	983
	L3	Bisrakh Road	Pre-monsoon	2149	1723	3080
			Post-monsoon	2095	2527	2930
	L4	Bisrakh Road	Pre-monsoon	2393	1695	2926
			Post-monsoon	2344	2340	2657
	L5	Bisrakh Road	Pre-monsoon	3310	2830	3642
			Post-monsoon	3068	3348	3173
	L6	Bisrakh Road	Pre-monsoon	1466	1019	1305
			Post-monsoon	1411	1108	1220
	L7	Khera Dharampura	Pre-monsoon	2029	1693	2298
			Post-monsoon	1965	1652	2101
	L8	Bishnuli	Pre-monsoon	2515	1715	2508
			Post-monsoon	2418	2250	2382
	L9	Achheja	Pre-monsoon	3118	1736	2888
			Post-monsoon	3025	2453	2790
Residential Zone	L10	Dairy Maccha	Pre-monsoon	1731	1475	1980
			Post-monsoon	1680	1607	1810
	L11	Dhoom Manikpur	Pre-monsoon	781	648	1050
			Post-monsoon	733	783	1015
	L12	Dhoom Manikpur	Pre-monsoon	1835	1058	1887
			Post-monsoon	1804	1295	1877
	L13	Badhpura	Pre-monsoon	2943	1431	3027
			Post-monsoon	2847	1656	2700

5.4.5.4 Turbidity

Analytical results of turbidity of waste water samples during study period are presented in Table – 5.4.5. During study period, turbidity value of waste water sample was recorded from 13 to 723 NTU.

Table – 5.4.5 Turbidity (in NTU) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	41	18	56
			Post-monsoon	22	13	23
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	38	30	45
			Post-monsoon	29	26	18
	L3	Bisrakh Road	Pre-monsoon	25	20	45
			Post-monsoon	22	15	16
	L4	Bisrakh Road	Pre-monsoon	77	25	51
			Post-monsoon	40	21	48
	L5	Bisrakh Road	Pre-monsoon	91	83	76
			Post-monsoon	40	55	29
	L6	Bisrakh Road	Pre-monsoon	67	88	77
			Post-monsoon	36	45	37
	L7	Khera Dharampura	Pre-monsoon	48	36	53
			Post-monsoon	15	13	44
	L8	Bishnuli	Pre-monsoon	130	238	218
			Post-monsoon	97	115	150
	L9	Achheja	Pre-monsoon	128	103	204
			Post-monsoon	98	77	151
Residential Zone	L10	Dairy Maccha	Pre-monsoon	230	139	140
			Post-monsoon	180	112	89
	L11	Dhoom Manikpur	Pre-monsoon	56	16	51
			Post-monsoon	32	44	29
	L12	Dhoom Manikpur	Pre-monsoon	545	691	723
			Post-monsoon	438	662	580
	L13	Badhpura	Pre-monsoon	46	35	75
			Post-monsoon	78	56	108

Agricultural waste water showed turbidity range of 13 to 56 NTU. Turbidity value of industrial waste water was recorded minimum 13 NTU at Khera Dharampura in post-monsoon of year 2017 and maximum 238 NTU at Bishnuli in pre-monsoon of year 2017. Domestic waste water has a wide range of turbidity value; from 16 to 723 NTU. Waste water sample L12 collected from Dhoom Manikpur showed exceptionally high turbidity. The source of high turbidity was effluent coming from cement industry present near to sampling location of L12. Fig. 5.4.4 explains the relation between mean concentration of turbidity in groundwater and waste water samples in three different zone of study area.

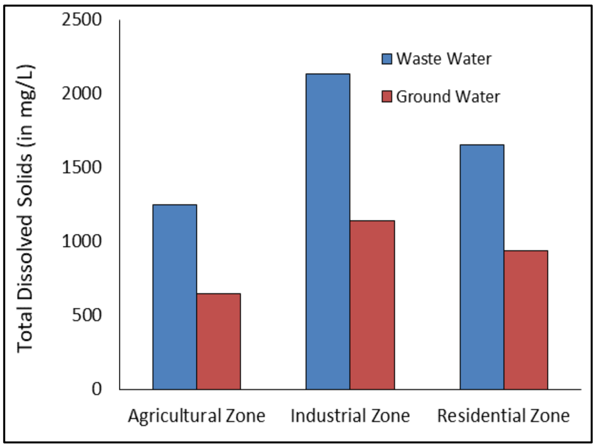


Fig. 5.4.3 Mean Total Dissolved Solids of Waste water and Groundwater samples in different zone of study area

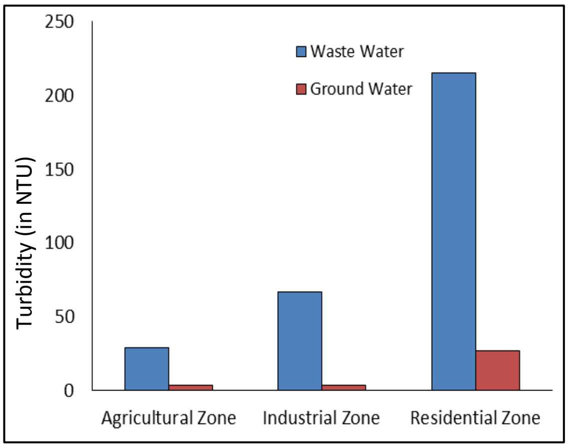


Fig. 5.4.4 Mean Turbidity of Waste water and Groundwater samples in different zone of study area

5.4.5.5 Total Hardness

Effluent of inorganic chemical industries and mining industries have very high value of total hardness (Pittyjohn, 1972). Waste water of construction sites, paper industry, sugar refining, petroleum refining, tanning industry and water treatment process also shows elevated level of hardness (Mc Quarrie, 1966). Magnesium and its alloys are used in textile, molds, die castings, paper industries, portable tools, tanning and in general household goods. Magnesium salts are utilized in fertilizers ceramics, explosives and medicines (Bech, 1966).

Analytical results of total hardness of waste water samples during study period are illustrated in Table – 5.4.6.

During the period under study, total hardness of waste water varied from 243 to 1190 mg/L. Maximum hardness was recorded from Badhpura nallah in pre-monsoon sample (L13) of year 2018 and minimum hardness was from Dhoom Manikpur nallah in pre-monsoon sample (L11) of year 2017. In agricultural zone, total hardness varied from 429 to 549 mg/L. Hardness of waste water of industrial zone gave a minimum value of 254 mg/L and a maximum value of 1079 mg/L. Total hardness in residential zone ranged between 243 and 1190 mg/L. Maximum mean total hardness (705 mg/L) was obtained from industrial zone of study area. Fig. 5.4.5 justifies the relation between mean total hardness in groundwater and waste water samples in three different zone of study area.

Table – 5.4.6 Total Hardness (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	447	466	549
			Post-monsoon	429	446	522
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	265	271	347
			Post-monsoon	254	256	321
	L3	Bisrakh Road	Pre-monsoon	847	868	1042
			Post-monsoon	824	852	992
	L4	Bisrakh Road	Pre-monsoon	847	858	1027
			Post-monsoon	828	815	929
	L5	Bisrakh Road	Pre-monsoon	549	576	625
			Post-monsoon	499	562	552
	L6	Bisrakh Road	Pre-monsoon	506	396	432
			Post-monsoon	482	383	414
	L7	Khera Dharampura	Pre-monsoon	697	731	860
			Post-monsoon	677	668	811
	L8	Bishnuli	Pre-monsoon	805	732	1017
			Post-monsoon	772	713	959
	L9	Achheja	Pre-monsoon	1008	903	1079
			Post-monsoon	1022	909	1040
Residential Zone	L10	Dairy Maccha	Pre-monsoon	554	538	640
			Post-monsoon	543	510	590
	L11	Dhoom Manikpur	Pre-monsoon	292	243	322
			Post-monsoon	279	255	306
	L12	Dhoom Manikpur	Pre-monsoon	790	608	691
			Post-monsoon	769	541	679
	L13	Badhpura	Pre-monsoon	1126	644	1190
			Post-monsoon	1108	644	1040

5.4.5.6 Calcium

Analytical results of calcium content of waste water samples during study period are presented in Table – 5.4.7. Calcium concentration of waste water collected from study area, ranged from 21.37 to 273 mg/L. In agricultural zone, calcium concentration was found between 60.54 and 75.48 mg/L.

Table - 5.4.7 Calcium (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	60.82	62.80	75.48
			Post-monsoon	62.13	60.54	71.84
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	32.37	32.80	42.34
			Post-monsoon	30.40	31.46	37.95
	L3	Bisrakh Road	Pre-monsoon	213.40	218.40	263.10
			Post-monsoon	208.00	215.20	248.90
	L4	Bisrakh Road	Pre-monsoon	223.50	226.90	273.00
			Post-monsoon	220.60	216.67	247.56
	L5	Bisrakh Road	Pre-monsoon	23.70	25.20	27.62
			Post-monsoon	21.37	23.70	24.13
	L6	Bisrakh Road	Pre-monsoon	91.08	71.60	78.71
			Post-monsoon	87.53	69.17	74.75
	L7	Khera Dharampura	Pre-monsoon	188.70	197.60	233.70
			Post-monsoon	185.00	178.90	218.00
	L8	Bishnuli	Pre-monsoon	175.30	159.20	212.60
			Post-monsoon	169.30	157.00	202.40
	L9	Achheja	Pre-monsoon	220.80	198.00	235.80
			Post-monsoon	222.60	197.40	227.70
Residential Zone	L10	Dairy Maccha	Pre-monsoon	65.00	62.40	74.00
			Post-monsoon	64.00	61.00	68.45
	L11	Dhoom Manikpur	Pre-monsoon	61.83	36.80	45.77
			Post-monsoon	57.12	34.36	43.40
	L12	Dhoom Manikpur	Pre-monsoon	57.61	43.20	58.67
			Post-monsoon	56.35	38.42	59.14
	L13	Badhpura	Pre-monsoon	108.20	66.80	125.40
			Post-monsoon	110.8	67.80	111.80

In industrial waste water, analysed calcium content was from 21.37 mg/L (from sample L5 of Bisrakh Road) to 273 mg/L (from sample L4 of Bisrakh Road). A range of 34.36 mg/L (from sample L11 of Dhoom Manikpur) to 125.4 mg/L (from sample L13 of Badhpura) of calcium was observed in domestic waste water. Fig. 5.4.6 describes the relation between mean concentration of calcium in groundwater and waste water samples in three different zone of study area.

Tariq et al., (2008) studied effects of effluent of tanning industries on groundwater quality in Kasur city of Pakistan. They reported mean calcium content of 187 mg/L in groundwater samples.

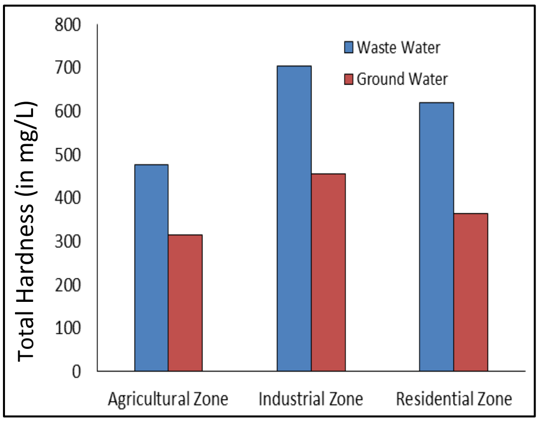


Fig. 5.4.5 Mean Total Hardness of Waste water and Groundwater samples in different zone of study area

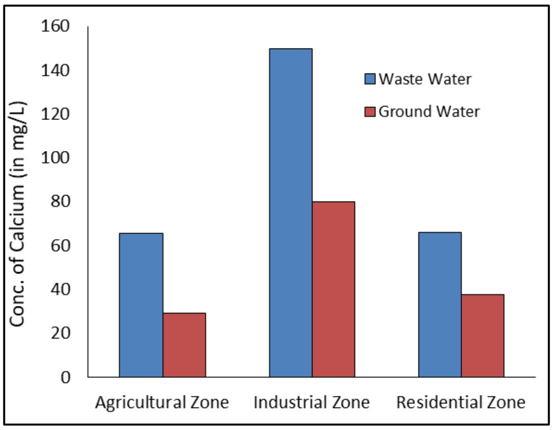


Fig. 5.4.6 Mean calcium concentration of Waste water and Groundwater samples in different zone of study area

5.4.5.7 Magnesium

Magnesium compounds are widely used in various industries. The hydroxides, carbonates, oxides, chlorides and sulphates of magnesium are used as a raw material in fertilizers industry, ceramic industry, pharmaceuticals, explosive industry etc. Magnesium alloys are used to make die casting and molds.

Analytical results of magnesium in waste water samples throughout the study period (2016, 2017 & 2018) are given in Table – 5.4.8.

The observed range of analysed magnesium in waste water samples was from 33.1 to 213.8 mg/L. Maximum mean value of magnesium was obtained from residential zone of study area. Increasing order of mean magnesium concentration in three different zone study area was – 76.0 (agricultural zone) < 80.51 (industrial zone) < 110.98 (residential zone). Magnesium content of waste water samples decreased in post-monsoon season due to dilution with rain water. Higher magnesium was obtained from samples taken from Bisrakh Road (L5), Achheja (L9), Dhoom Manikpur nallah and Badhpura nallah. Fig. 5.4.7 presented mean concentration of magnesium in groundwater and waste water samples in three different zone of study area.

Magnesium content of groundwater was found high in groundwater samples of Kasur city of Pakistan due to effluent of tanning industry (Tariq et al., 2008).

Table – 5.4.8 Magnesium (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	71.84	74.16	87.99
			Post-monsoon	66.68	71.86	83.49
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	44.81	45.36	58.87
			Post-monsoon	43.37	43.27	55.16
	L3	Bisrakh Road	Pre-monsoon	76.58	78.24	93.79
			Post-monsoon	74.18	76.64	90.10
	L4	Bisrakh Road	Pre-monsoon	70.30	70.60	84.00
			Post-monsoon	67.56	66.56	75.56
	L5	Bisrakh Road	Pre-monsoon	119.50	123.00	135.70
			Post-monsoon	108.60	122.50	119.80
	L6	Bisrakh Road	Pre-monsoon	67.80	52.08	57.32
			Post-monsoon	64.31	51.14	55.45
	L7	Khera Dharampura	Pre-monsoon	55.04	56.88	67.26
			Post-monsoon	52.39	53.76	64.90
	L8	Bishnuli	Pre-monsoon	89.42	81.20	118.39
			Post-monsoon	85.16	78.25	110.50
	L9	Achheja	Pre-monsoon	111.20	99.14	119.30
			Post-monsoon	113.50	101.40	114.70
Residential Zone	L10	Dairy Maccha	Pre-monsoon	95.54	91.68	110.88
			Post-monsoon	93.50	87.29	102.20
	L11	Dhoom Manikpur	Pre-monsoon	33.40	36.24	50.70
			Post-monsoon	33.10	38.15	48.18
	L12	Dhoom Manikpur	Pre-monsoon	157.54	120.00	132.80
			Post-monsoon	153.20	108.50	129.50
	L13	Badhpura	Pre-monsoon	208.60	114.50	213.80
			Post-monsoon	202.80	115.70	185.60

5.4.5.8 Sodium

Sodium content of waste water of study area was recorded in a great variation. Analytical results of sodium in waste water samples throughout the study period (2016, 2017 & 2018) are given in Table – 5.4.9.

The minimum sodium concentration (78.7 mg/L) was recorded from Dhoom Manikpur nallah in post-monsoon sample of year 2016 while maximum (791.9 mg/L) was recorded from Bisrakh Road (L5) in pre-monsoon sample of year 2018. Sodium content of analysed waste water samples in agricultural zone, ranged from 122.7 mg/L to 160.3 mg/L. Sodium content of industrial waste water was found to vary from 109.7 to 791.9 mg/L. Sodium of domestic waste water was recorded minimum of 78.7 mg/L in Dhoom Manikpur nallah (L11) and maximum of 361.8 mg/L in Badhpura Nallah (L13). Mean sodium content of waste water samples were very much higher tha mean sodium content of groundwater samples (Fig. 5.4.8). Mean sodium concentration in waste water samples was found highest in industrial zone of study area. The calculated value of mean sodium concentration in different zone of area was; 305.58 (Industrial) > 189.52 (Residential) > 137.83 (Agricultural). Domestic sewage is an important source of sodium in waste water.

Naveen et al., (2016) analysed a range of 3016 to 3710 mg/L of sodium in leachates originated from Mavallipura landfill site in Bangalore. Similar type of study was done by Kamble & Saxena, (2016) in Jawaharnagar village of Telangana.

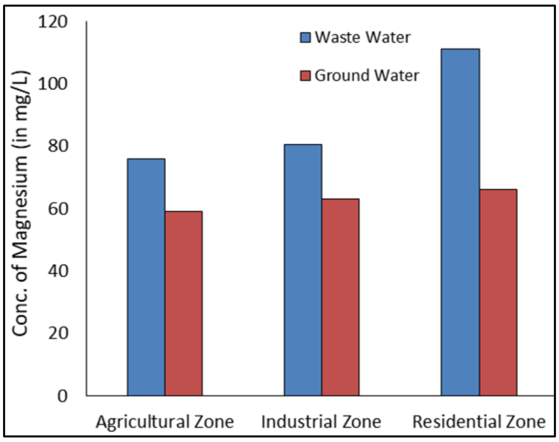


Fig. 5.4.7 Mean magnesium concentration of Waste water and Groundwater samples in different zone of study area

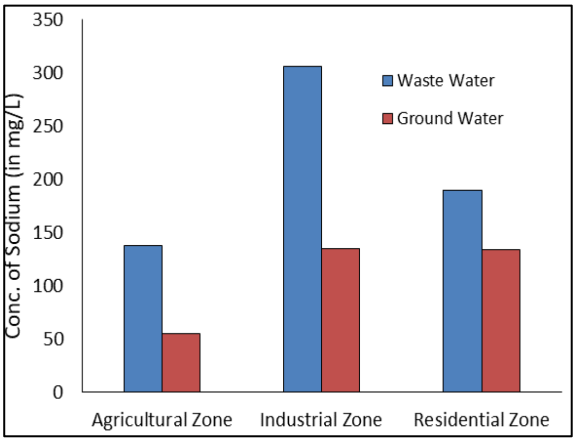


Fig. 5.4.8 Mean Sodium concentration of Waste water and Groundwater samples in different zone of study area

Table – 5.4.9 Sodium (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	129.60	133.70	160.30
			Post-monsoon	122.70	130.40	150.30
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	114.10	116.30	150.20
			Post-monsoon	109.70	114.60	139.20
	L3	Bisrakh Road	Pre-monsoon	273.50	280.10	335.10
			Post-monsoon	264.30	277.40	317.30
	L4	Bisrakh Road	Pre-monsoon	276.87	283.20	340.56
			Post-monsoon	272.50	270.00	308.63
	L5	Bisrakh Road	Pre-monsoon	705.40	720.80	791.90
			Post-monsoon	665.90	716.40	688.20
	L6	Bisrakh Road	Pre-monsoon	213.90	165.30	183.80
			Post-monsoon	208.20	162.40	173.60
	L7	Khera Dharampura	Pre-monsoon	190.80	201.90	240.30
			Post-monsoon	187.10	182.70	229.80
	L8	Bishnuli	Pre-monsoon	338.50	308.60	315.50
			Post-monsoon	324.00	305.40	299.40
	L9	Achheja	Pre-monsoon	435.70	245.70	277.40
			Post-monsoon	431.60	246.20	268.10
Residential Zone	L10	Dairy Maccha	Pre-monsoon	257.00	244.00	292.10
			Post-monsoon	247.50	235.67	264.70
	L11	Dhoom Manikpur	Pre-monsoon	82.77	95.95	123.80
			Post-monsoon	78.70	99.70	125.10
	L12	Dhoom Manikpur	Pre-monsoon	116.30	88.82	118.40
			Post-monsoon	114.80	79.61	115.80
	L13	Badhpura	Pre-monsoon	361.80	202.10	351.30
			Post-monsoon	352.4	198.60	301.60

5.4.5.9 Potassium

Potassium content of waste water of study area was recorded in a great variation. Analytical results of potassium in waste water samples throughout the study period (2016, 2017 & 2018) are given in Table – 5.4.10.

The minimum potassium concentration (8.31 mg/L) was recorded from Dhoom Manikpur nallah in post-monsoon sample of year 2017 while maximum (162.7 mg/L) was recorded from Khera Dharampura (L12) in pre-monsoon sample of year 2018.

Table – 5.4.10 Potassium (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	36.86	38.10	45.32
			Post-monsoon	37.15	36.34	42.05
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	24.69	25.95	32.74
			Post-monsoon	25.95	23.47	29.12
	L3	Bisrakh Road	Pre-monsoon	54.78	56.00	67.10
			Post-monsoon	52.14	54.34	64.75
	L4	Bisrakh Road	Pre-monsoon	53.89	56.00	68.45
			Post-monsoon	51.50	54.56	62.99
	L5	Bisrakh Road	Pre-monsoon	56.62	58.80	64.58
			Post-monsoon	52.50	59.60	56.28
	L6	Bisrakh Road	Pre-monsoon	37.43	29.60	32.46
			Post-monsoon	35.46	29.02	29.84
	L7	Khera Dharampura	Pre-monsoon	130.20	138.10	162.70
			Post-monsoon	125.30	127.90	153.60
	L8	Bishnuli	Pre-monsoon	101.00	92.85	88.92
			Post-monsoon	96.76	90.89	84.37
	L9	Achheja	Pre-monsoon	95.16	87.43	102.80
			Post-monsoon	97.45	87.12	98.72
Residential Zone	L10	Dairy Maccha	Pre-monsoon	37.70	36.35	43.00
			Post-monsoon	36.50	36.25	40.00
	L11	Dhoom Manikpur	Pre-monsoon	42.23	45.83	55.06
			Post-monsoon	45.70	43.12	52.14
	L12	Dhoom Manikpur	Pre-monsoon	12.50	9.00	12.73
			Post-monsoon	13.51	8.31	11.81
	L13	Badhpura	Pre-monsoon	123.40	88.00	144.50
			Post-monsoon	112.90	87.80	127.50

Potassium content of analysed waste water samples in agricultural zone extended from 23.47 mg/L to 162.7 mg/L. Potassium content of industrial waste water was found from 109.7 to 791.9 mg/L. Potassium of domestic waste water was recorded minimum of 8.31 mg/L in Dhoom Manikpur nallah (L12) and maximum 144.5 mg/L in Badhpura nallah (L13). Mean potassium content of waste water samples were very much higher tha mean potassium content of groundwater samples (Fig. 5.4.9). Mean potassium concentration in waste water samples was found highest in industrial zone of study area. The calculated value of mean potassium concentration in different zone of area was; 70.04 (Industrial) > 52.74 (Residential) > 39.30 (Agricultural). Compounds of potassium are utilized in the manufacturing of fertilizers, glass, baking powder, soft drinks, explosives, pigments etc. A big rice mill was present in Khera Darampura village and effluent of rice industry contains a considerable amount of potassium. Occurrence of high concentration of potassium in waste water samples collected from Khera Dharampura village can be attributed to effluents discharged from rice industry. A concentration of 298 mg/L potassium in effluent of rice mill in Burdwan district of West Bengal, was documented by Dutta et al., (2015).

5.4.5.10 BORON

A widely used compound of boron is borax which is required for the manufacturing of heat resistant glasses, fiberglass, fertlizers, detergents, porcelain etc. The domestic waste water contains a considerable amount of borate from cleaning agents. Sodium tetra-borate (borax) is widely used as a cleaning aid for which it may be present in sewage and industrial waste. Boric acid, borates, and perborates are used in antiseptics, cosmetic products, medicines (as pH buffers), boron neutron capture therapy, fertilizers and pesticides.

Analytical results of boron in waste water samples throughout the study period (2016, 2017 & 2018) are given in Table – 5.4.11. During the period under study, boron of waste water varied from 1.05 to 8.55 mg/L. Maximum boron content was recorded from Bisrakh Road station in pre-monsoon sample (L4) of year 2017 and minimum boron was from Dairy Maccha station in post-monsoon sample (L10) of year 2018. In agricultural zone boron ranged from 3.087 to 3.846 mg/L. Boron of waste water of industrial zone gave a minimum value of 2.18 mg/L and a maximum value of 8.55 mg/L. Boron in residential zone ranged between 1.05 and 4.34 mg/L. Deceasing order of mean boron concentration in waste water samples of three different zone of study area was; 4.22 (industrial) > 3.36 (agricultural) > 2.71 (residential). Relative mean concentration of boron in groundwater and waste water samples are given in Fig. 5.4.10.

Abdalla & Khalil, (2018) demonstrated mixing of groundwater and waste water in 94% of analysed samples of Qus city of Egypt.

Table – 5.4.11 Boron (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	3.185	3.180	3.846
			Post-monsoon	3.087	3.126	3.751
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	3.280	3.414	4.230
			Post-monsoon	3.172	3.470	3.690
	L3	Bisrakh Road	Pre-monsoon	5.390	5.610	6.710
			Post-monsoon	5.128	3.380	3.370
	L4	Bisrakh Road	Pre-monsoon	4.660	8.550	5.400
			Post-monsoon	4.320	6.390	4.810
	L5	Bisrakh Road	Pre-monsoon	5.398	5.610	6.270
			Post-monsoon	4.812	5.480	5.350
	L6	Bisrakh Road	Pre-monsoon	4.658	3.660	4.036
			Post-monsoon	4.430	3.187	3.734
	L7	Khera Dharampura	Pre-monsoon	2.490	2.640	3.150
			Post-monsoon	2.425	2.670	2.893
	L8	Bishnuli	Pre-monsoon	4.465	4.150	4.130
			Post-monsoon	4.276	4.050	4.150
	L9	Achheja	Pre-monsoon	4.120	3.830	2.216
			Post-monsoon	3.673	3.680	2.180
Residential Zone	L10	Dairy Maccha	Pre-monsoon	2.210	2.580	1.430
			Post-monsoon	3.340	4.330	1.050
	L11	Dhoom Manikpur	Pre-monsoon	1.560	1.890	2.710
			Post-monsoon	1.360	1.670	2.830
	L12	Dhoom Manikpur	Pre-monsoon	3.010	2.370	3.450
			Post-monsoon	3.520	2.186	3.500
	L13	Badhpura	Pre-monsoon	1.780	3.560	3.550
			Post-monsoon	3.870	4.340	2.890

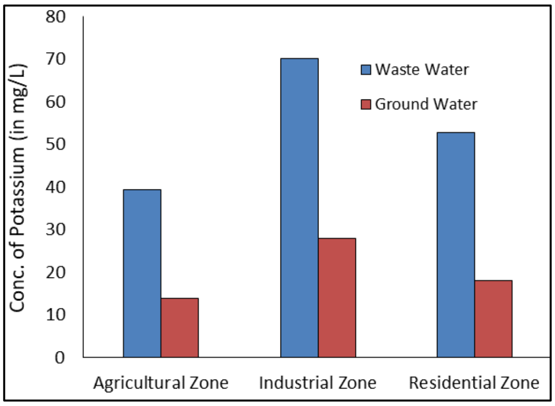


Fig. 5.4.9 Mean Potassium concentration of Waste water and Groundwater samples in different zone of study area

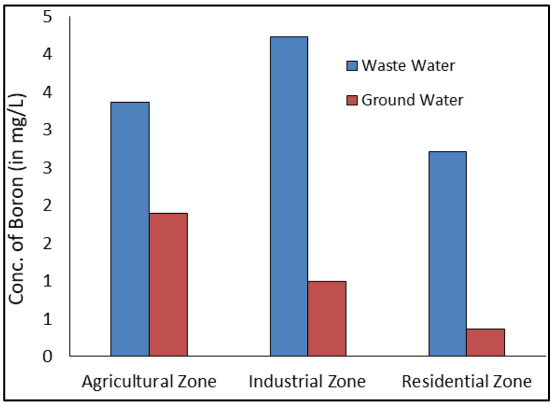


Fig. 5.4.10 Mean Boron concentration of Waste water and Groundwater samples in different zone of study area

5.4.5.11 Total Alkalinity

Alkalinity of water is due to presence of ions like HCO_3^-, CO_3^{2-}, PO_4^{2-}, BO_3^{3-}, SiO_4^{4-}, OH^- etc. Analytical results of total alkalinity of waste water samples during study period are presented in Table - 5.4.12.

Results of study concluded that there was a wide variation in total alkalinity value (158.33-1200.8 mg/L) with a mean value of 447.96 mg/L. Highest mean alkalinity (550.80 mg/L) was obtained from residential zone of study area. The analysed range of alkalinity in agricultural area was 296.58 – 357.42 mg/L. In industrial zone, its range was 208.25 – 657.5 mg/L. Higher alkalinity was analysed in waste water samples collected from Badhpura nallah due to dissolution of more ions of domestic effluent. Relative mean concentration of total alkalinity in groundwater and waste water samples are given in Fig. 5.4.11.

High alkalinity in groundwater samples of industrial sites of district Haridwar was observed by Matta et al., (2016). Naveen et al., (2016) analysed leachate samples of Mavallipura landfills sites in Bangalore and reported total alkalinity range of 10800 to 11,200 mg/L.

Table – 5.4.12 Total Alkalinity (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	338.17	299.25	357.42
			Post-monsoon	317.98	296.58	347.92
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	216.92	212.33	275.17
			Post-monsoon	211.25	208.25	254.00
	L3	Bisrakh Road	Pre-monsoon	449.50	547.92	657.50
			Post-monsoon	438.05	540.33	627.25
	L4	Bisrakh Road	Pre-monsoon	390.00	398.83	477.63
			Post-monsoon	379.27	380.04	435.53
	L5	Bisrakh Road	Pre-monsoon	499.40	510.43	561.05
			Post-monsoon	462.65	499.98	494.23
	L6	Bisrakh Road	Pre-monsoon	449.00	339.00	372.25
			Post-monsoon	427.42	331.17	352.83
	L7	Khera Dharampura	Pre-monsoon	384.00	403.33	482.33
			Post-monsoon	370.83	367.83	459.08
	L8	Bishnuli	Pre-monsoon	383.58	348.58	366.70
			Post-monsoon	367.50	341.50	346.55
	L9	Achheja	Pre-monsoon	472.58	420.92	500.00
			Post-monsoon	450.92	416.22	482.47
Residential Zone	L10	Dairy Maccha	Pre-monsoon	339.58	322.75	387.50
			Post-monsoon	330.08	313.75	353.89
	L11	Dhoom Manikpur	Pre-monsoon	193.75	187.00	248.67
			Post-monsoon	158.33	190.50	237.83
	L12	Dhoom Manikpur	Pre-monsoon	737.42	566.42	838.96
			Post-monsoon	732.00	543.58	828.23
	L13	Badhpura	Pre-monsoon	1150.00	635.75	1200.83
			Post-monsoon	1048.33	633.25	1040.83

5.4.5.12 Chloride

The chloride content of waste water is high because its main source is table salt; sodium chloride (NaCl). It is an important ingredient of food and comes out from body with excreta. In coastal areas, chloride ions are present in sewage effluent due to intrusion of salty water of sea. Industrial activities also enhanced the chloride content of effluent.

Analytical results of chloride content of waste water samples during study period are presented in Table – 5.4.13.

Table – 5.4.13 Chloride (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	160.60	166.60	201.90
			Post-monsoon	156.80	163.40	192.80
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	67.82	68.60	89.08
			Post-monsoon	66.79	66.97	80.95
	L3	Bisrakh Road	Pre-monsoon	115.60	307.80	370.40
			Post-monsoon	112.40	305.70	350.90
	L4	Bisrakh Road	Pre-monsoon	442.30	450.00	541.00
			Post-monsoon	434.56	445.56	491.45
	L5	Bisrakh Road	Pre-monsoon	219.90	225.40	247.80
			Post-monsoon	205.10	218.90	216.50
	L6	Bisrakh Road	Pre-monsoon	165.40	127.40	140.80
			Post-monsoon	156.10	124.10	132.80
	L7	Khera Dharampura	Pre-monsoon	138.70	147.00	177.60
			Post-monsoon	133.50	135.80	167.30
	L8	Bishnuli	Pre-monsoon	392.40	356.80	355.20
			Post-monsoon	375.70	350.70	337.10
	L9	Achheja	Pre-monsoon	615.40	448.20	530.70
			Post-monsoon	575.80	455.70	513.80
Residential Zone	L10	Dairy Maccha	Pre-monsoon	350.50	333.20	400.00
			Post-monsoon	341.70	322.50	365.50
	L11	Dhoom Manikpur	Pre-monsoon	110.10	127.40	168.40
			Post-monsoon	113.50	130.80	165.30
	L12	Dhoom Manikpur	Pre-monsoon	294.00	225.40	299.70
			Post-monsoon	286.57	197.80	303.70
	L13	Badhpura	Pre-monsoon	303.90	166.60	272.70
			Post-monsoon	298.70	153.40	240.80

Chloride concentration of agricultural waste water of study area ranged from 156.8 to 201.9 mg/L. Chloride concentration of waste water from all industries was found to be in the range of 66.79 to 615.4 mg/L giving a mean value 274.91 mg/L. In industrial zone, minimum chloride content was recorded from the waste water sample taken from Bisrakh Road (L2) while maximum was recorded from sample L9 collected from Achheja. Chloride content of domestic waste water of study area was also very high (ranged from 110.1 to 400 mg/L). Chloride content of Dhoom Manikpur nallah was recorded minimum while the maximum was recorded from Dairy Maccha nallah. High chloride content in waste water samples of residential zone indicates discharge of sewage water. Excreta of human beings and other animals contains high amount of chlorides along with nitrogenous compounds. Nearly 8-15 gms of sodium chloride is excreted by a healthy human in a day (Trivedy & Goyal, 1986). Fig. 5.4.12 describes the relation between mean content of chloride in groundwater and waste water samples in three different zone of study area. Adverse effect of waste water on groundwater chloride concentration was studied by McArthur et al., (2012) in parts of West Bengal and Bangladesh. Naveen et al., (2016) analysed a range of 660 to 780 mg/L of chloride in leachates originated from Mavallipura landfill site in Bangalore.

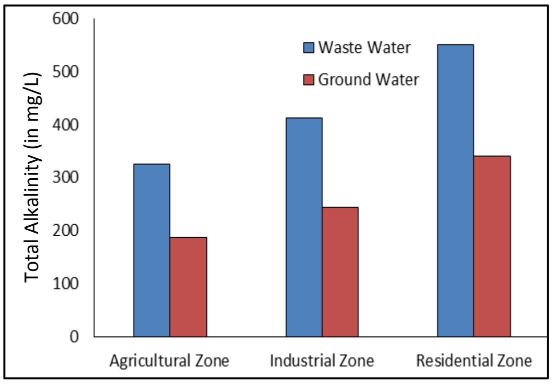


Fig. 5.4.11 Mean Total Alkalinity concentration of Waste water and Groundwater samples in different zone of study area

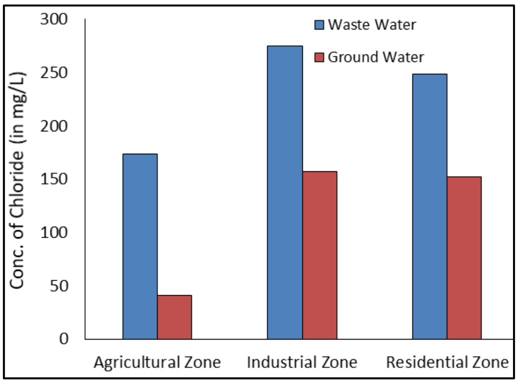


Fig. 5.4.12 Mean Chloride concentration of Waste water and Groundwater samples in different zone of study area

5.4.5.13 Fluoride

Fluoride compounds are extensively used in aluminum industry and components of phosphate fertilizers, bricks, tiles and ceramics etc. Now-a-days fluoride finds its use in various pharmaceutical products including toothpaste and vitamin supplements.

Analytical results of fluoride in waste water samples throughout the study period (2016, 2017 & 2018) are given in Table – 5.4.14.

During the period under study, fluoride of waste water varied from 0.4 to 1.84 mg/L. Maximum fluoride content was recorded from Achheja station in pre-monsoon sample (L9) of year 2016 and minimum fluoride was obtained from Dairy Maccha station in pre-monsoon sample (L10) of year 2017. In agricultural zone fluoride ranged from 0.42 to 0.52 mg/L. Fluoride of waste water of industrial zone gave a minimum value of 0.42 mg/L and a maximum value of 1.84 mg/L. Fluoride in residential zone ranged between 0.40 and 1.7 mg/L. Deceasing order of mean fluoride concentration in waste water samples of three different zone of study area was; 0.78 (residential) > 0.76 (industrial) > 0.45 (agricultural). Relative mean concentration of fluoride in groundwater and waste water samples are given in Fig. 5.4.13.

Kanagaraj & Elango, (2019) investigated fluoride content of groundwater around leather tanning industries in Vellore district of Tamil Nadu. Nearly 37% samples have fluoride content above acceptable limit.

Table – 5.4.14 Fluoride (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	0.43	0.43	0.52
			Post-monsoon	0.42	0.42	0.49
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	0.71	0.72	0.83
			Post-monsoon	0.68	0.63	0.76
	L3	Bisrakh Road	Pre-monsoon	0.44	0.46	0.54
			Post-monsoon	0.42	0.43	0.52
	L4	Bisrakh Road	Pre-monsoon	0.50	0.57	0.56
			Post-monsoon	0.48	0.51	0.88
	L5	Bisrakh Road	Pre-monsoon	0.46	0.57	0.62
			Post-monsoon	0.44	0.55	0.54
	L6	Bisrakh Road	Pre-monsoon	0.84	0.64	0.71
			Post-monsoon	0.79	0.60	0.58
	L7	Khera Dharampura	Pre-monsoon	0.50	0.51	0.62
			Post-monsoon	0.47	0.46	0.58
	L8	Bishnuli	Pre-monsoon	1.24	1.14	1.14
			Post-monsoon	1.20	1.17	1.07
	L9	Achheja	Pre-monsoon	1.84	1.31	1.16
			Post-monsoon	1.72	1.19	1.02
Residential Zone	L10	Dairy Maccha	Pre-monsoon	0.50	0.40	0.43
			Post-monsoon	0.46	0.45	0.99
	L11	Dhoom Manikpur	Pre-monsoon	0.85	0.51	0.99
			Post-monsoon	0.78	0.53	0.78
	L12	Dhoom Manikpur	Pre-monsoon	0.73	0.57	0.73
			Post-monsoon	0.73	0.49	0.70
	L13	Badhpura	Pre-monsoon	1.70	0.78	1.02
			Post-monsoon	1.46	1.09	0.99

5.4.5.14 Nitrite

Analytical results of nitrite content of waste water samples during study period are presented in Table – 5.4.15. The analysed range of nitrite in waste water samples was from 1.82 to 15.2 mg/L with a mean value of 5.419 mg/L. Nitrite of agricultural waste water ranged from 3.58 to 5.73 mg/L. Nitrite concentration of waste water from all industries was found to be in the range of 2.1 to 13.65 mg/L with a mean value 4.53 mg/L.

Table – 5.4.15 Nitrite (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	3.80	3.81	4.47
			Post-monsoon	3.58	5.73	4.26
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	2.43	2.56	3.22
			Post-monsoon	2.35	2.71	2.86
	L3	Bisrakh Road	Pre-monsoon	4.18	4.33	5.09
			Post-monsoon	4.15	3.98	4.53
	L4	Bisrakh Road	Pre-monsoon	2.10	2.55	4.22
			Post-monsoon	2.65	2.28	2.56
	L5	Bisrakh Road	Pre-monsoon	6.37	3.44	3.68
			Post-monsoon	5.89	3.27	3.30
	L6	Bisrakh Road	Pre-monsoon	3.54	2.80	3.18
			Post-monsoon	3.26	2.44	3.04
	L7	Khera Dharampura	Pre-monsoon	4.06	5.33	5.39
			Post-monsoon	3.74	3.85	4.12
	L8	Bishnuli	Pre-monsoon	4.54	4.22	5.17
			Post-monsoon	4.39	3.98	3.99
	L9	Achheja	Pre-monsoon	13.65	11.42	9.24
			Post-monsoon	12.23	7.52	7.46
Residential Zone	L10	Dairy Maccha	Pre-monsoon	14.76	13.32	15.00
			Post-monsoon	15.20	13.56	13.01
	L11	Dhoom Manikpur	Pre-monsoon	1.97	2.13	3.85
			Post-monsoon	1.82	2.27	2.73
	L12	Dhoom Manikpur	Pre-monsoon	8.24	5.87	12.34
			Post-monsoon	9.33	8.16	13.59
	L13	Badhpura	Pre-monsoon	4.41	2.30	5.43
			Post-monsoon	4.39	2.31	3.78

In industrial zone, minimum nitrite concentration was recorded from the waste water sample taken from Bisrakh Road (L4) while maximum was recorded from sample L9 collected from Achheja. Nitrite content of domestic waste water of study area was also very high (ranged from 1.82 to 15.2 mg/L). Nitrite content of Dhoom Manikpur nallah (L11) was recorded minimum while the maximum was recorded from Dairy Maccha nallah (L10). Fig. 5.4.14 explains the relation between mean concentration of nitrite in groundwater and waste water samples in three different zone of study area.

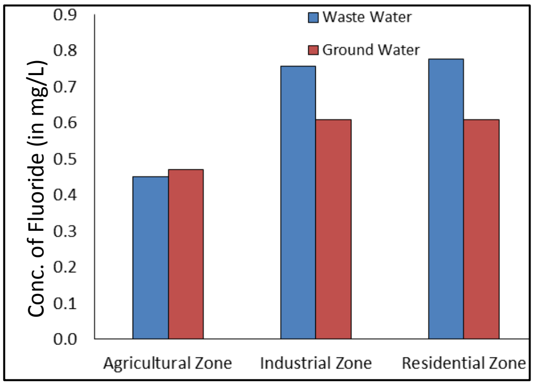


Fig. 5.4.13 Mean Fluoride concentration of Waste water and Groundwater samples in different zone of study area

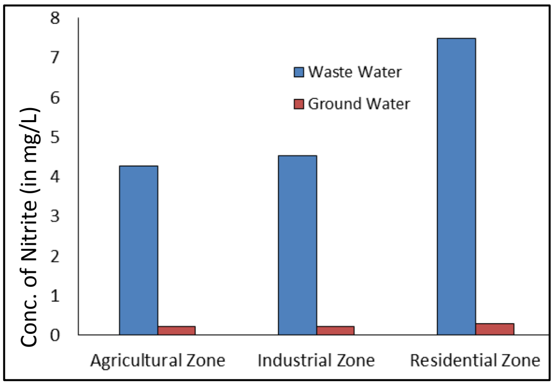


Fig. 5.4.14 Mean Nitrite concentration of Waste water and Groundwater samples in different zone of study area

5.4.5.15 Nitrate

Nitrates are widely used in fertilizers, explosives, food preservatives and as oxidizing agents in chemical industries. The sources of nitrate in waste water are sewage discharge, agricultural runoffs, decayed animals, vegetables and leachate from refuse dumps. Potassium nitrate and ammonium nitrate, two majorly used fertilizers, are main sources of nitrate in agricultural run-offs.

Analytical results of nitrate concentration in waste water samples during study period are presented in Table – 5.4.16.

The obtained range of nitrate in waste water samples was from 35 to 868 mg/L. In agricultural zone of study area nitrate concentration varied from 306.8 to 384.2 mg/L with a mean value 335.82 mg/L. Industrial zone of study area has wide range of nitrate with a minimum value of 295.9 mg/L and maximum value of 868 mg/L. Waste water of residential zone also showed high nitrate value (35 to 398.4 mg/L). In industrial zone, waste water of Bisrakh road (L2) showed a minimum nitrate concentration while Khera Dharampura (L7) showed a maximum nitrate concentration. The decreasing order of calculated mean nitrate value in three types of zone was; 446.69 mg/L (industrial zone) < 335.82 mg/L (agricultural zone) < 216.28 mg/L (residential zone). Fig. 5.4.15 illustrates the relation between mean concentration of nitrate in groundwater and waste water samples in three different zone of study area. Nitrate concentration of 30 mg/L in well water of Dasdia in West Bengal was observed by Mc Arthur et al., (2012). They concluded that well water was contaminated with waste water upto 60%. High nitrate content was obtained from shallow wells near to septic tanks, of Douala in Cameroon (Wirmvem et al., 2017).

Table – 5.4.16 Nitrate (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	311.30	321.00	384.20
			Post-monsoon	306.80	325.60	366.00
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	304.00	298.00	385.40
			Post-monsoon	295.90	303.00	353.60
	L3	Bisrakh Road	Pre-monsoon	516.40	528.00	632.60
			Post-monsoon	505.90	515.70	605.20
	L4	Bisrakh Road	Pre-monsoon	318.70	324.00	387.78
			Post-monsoon	311.50	306.45	351.56
	L5	Bisrakh Road	Pre-monsoon	557.60	568.00	625.80
			Post-monsoon	517.50	557.60	545.50
	L6	Bisrakh Road	Pre-monsoon	415.80	320.00	353.00
			Post-monsoon	397.00	322.60	337.40
	L7	Khera Dharampura	Pre-monsoon	823.60	868.00	742.00
			Post-monsoon	795.90	516.90	604.90
	L8	Bishnuli	Pre-monsoon	415.90	379.00	376.20
			Post-monsoon	400.20	371.50	358.40
	L9	Achheja	Pre-monsoon	345.40	310.00	372.30
			Post-monsoon	328.70	311.70	359.10
Residential Zone	L10	Dairy Maccha	Pre-monsoon	323.50	309.00	372.00
			Post-monsoon	311.70	311.70	337.20
	L11	Dhoom Manikpur	Pre-monsoon	46.80	35.00	57.82
			Post-monsoon	44.89	41.75	51.09
	L12	Dhoom Manikpur	Pre-monsoon	170.20	130.00	193.90
			Post-monsoon	175.10	129.56	198.30
	L13	Badhpura	Pre-monsoon	372.40	210.00	398.40
			Post-monsoon	375.80	213.00	381.60

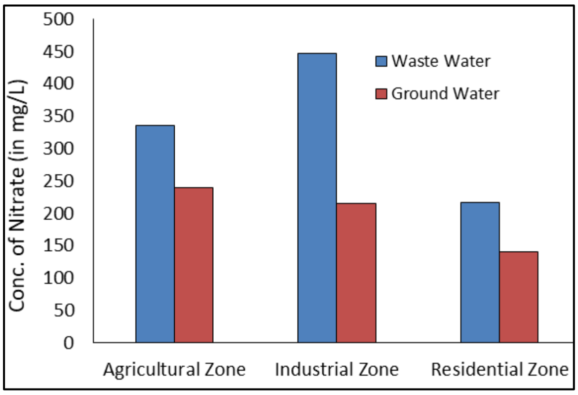
5.4.5.16 Phosphate

The two major source of phosphate in environment are application of phosphate rich fertilizers and use of detergents in cleaning. Phosphate compounds are also used in various foodstuffs, like cheese, sausages and hams. Phosphate is frequently present in municipal and agricultural waste water (Trivedy et al., 1987). Analytical results of phosphate of waste water samples during study period are presented in Table – 5.4.17.

During study period of three years, phosphate concentration in waste water of study area ranged from 1.07 to 8.12 mg/L with a mean value of 4.80 mg/L. Its minimum concentration was recorded from Badhpura nallah in pre-monsoon sample of year 2017. Dairy Maccha nallah in year 2018 gave the maximum value of phosphate concentration. In agricultural zone of study area phosphate concentration varied from 3.17 to 4.14 mg/L with a mean value of 3.51 mg/L. In industrial zone, minimum value of 3 mg/L (at Bisrakh Road station in year 2016) and maximum value of 7.55 mg/L (at Achheja water quality station in year 2018) of phosphate was observed. In residential zone, Badhpura nallah in year 2017 showed a minimum value of phosphate (1.07 mg/L) and nallah coming from Dairy Maccha in year 2016 showed a maximum value of phosphate (8.12 mg/L). Mean value of phosphate was found maximum in residential zone of study area. The decreasing order of mean value of phosphate in study area was 5.10 mg/L (residential zone) > 4.28 mg/L (industrial zone) > 3.51 mg/L (agricultural zone). The detergent rich waste water and agricultural run-offs are rich in phosphate ions. Discharge of these wastes results into high phosphate level in waste water of residential and agricultural area. Fig. 5.4.16 explains the relation between mean concentration of phosphate in groundwater and waste water samples in three different zone of study area.

Table – 5.4.17 Phosphate (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	3.25	3.37	4.14
			Post-monsoon	3.17	3.28	3.84
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	4.26	4.40	5.62
			Post-monsoon	4.23	4.21	5.15
	L3	Bisrakh Road	Pre-monsoon	3.23	3.19	3.83
			Post-monsoon	3.13	3.14	3.62
	L4	Bisrakh Road	Pre-monsoon	3.48	3.83	4.12
			Post-monsoon	3.00	3.12	3.89
	L5	Bisrakh Road	Pre-monsoon	3.71	3.89	4.17
			Post-monsoon	3.47	3.41	3.53
	L6	Bisrakh Road	Pre-monsoon	5.59	4.22	4.74
			Post-monsoon	5.29	4.15	4.52
	L7	Khera Dharampura	Pre-monsoon	6.60	5.89	5.07
			Post-monsoon	6.50	6.16	4.71
	L8	Bishnuli	Pre-monsoon	6.41	5.84	5.98
			Post-monsoon	6.16	5.71	5.65
	L9	Achheja	Pre-monsoon	7.33	5.61	7.55
			Post-monsoon	6.14	6.56	7.13
Residential Zone	L10	Dairy Maccha	Pre-monsoon	7.20	6.38	8.12
			Post-monsoon	6.26	6.98	7.12
	L11	Dhoom Manikpur	Pre-monsoon	7.13	3.56	3.16
			Post-monsoon	6.51	4.74	3.11
	L12	Dhoom Manikpur	Pre-monsoon	7.35	5.15	6.11
			Post-monsoon	7.21	4.13	6.03
	L13	Badhpura	Pre-monsoon	2.81	1.07	4.12
			Post-monsoon	2.57	2.10	3.55



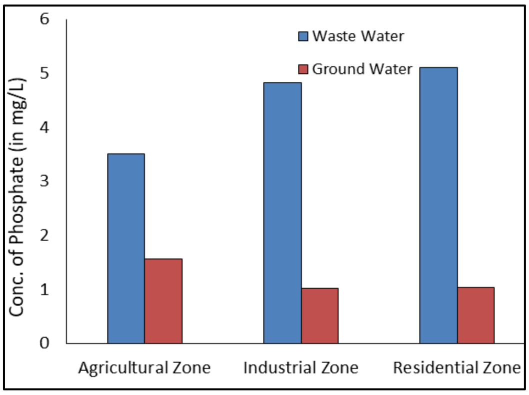


Fig. 5.4.15 Mean Nitrate concentration of Waste water and Groundwater samples in different zone of study area

Fig. 5.4.16 Mean Phosphate concentration of Waste water and Groundwater samples in different zone of study area

5.4.5.17 Sulphate

Generally high concentration of sulphate in river may be due to oxidation of sulphates of metals which is present in industrial effluent (Delisle & Schmidt, 1977). Atmospheric SO_2 emitted by the metallurgical roasting processes and generated by the combustion of fossil fuels also added a significant amount of sulphate to water bodies.

Analytical results of sulphate of waste water samples during study period are presented in Table – 5.4.18. The sulphate concentration in waste water of study area ranged from 2.97 to 883.9 mg/L with a mean value of 220.69 mg/L. On the basis of land use pattern in current study area, sulphate concentration in waste water has significant variations. In agricultural zone, sulphate concentration ranged from 47.37 to 61.4 mg/L with a mean value of 52.81 mg/L. Sulphate analysis of waste water of industrial zone gave a minimum value of 2.97 mg/L and a maximum value of 883.9 mg/L with a mean of 272.75 mg/L. The sulphate concentration in residential zone ranged between 58.87 and 281.2 mg/L providing a mean of 158.55 mg/L. The mean value of sulphate in waste water of industrial area may be attributed to dumping of industrial effluent without proper treatment. Fig. 5.4.17 explains the relation between mean concentration of sulphate in groundwater and waste water samples in three different zone of study area. Impact of waste water on groundwater sulphate concentration was studied by McArthur et al., (2012) in parts of West Bengal and Bangladesh. As compare to dry season, lesser concentration of sulphate was obtained in leachate samples collected in wet season (Kamble & saxena, 2016).

Table – 5.4.18 Sulphate (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	49.87	51.00	61.40
			Post-monsoon	47.37	49.89	57.33
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	30.07	3.11	40.04
			Post-monsoon	28.17	2.97	36.74
	L3	Bisrakh Road	Pre-monsoon	278.30	287.00	345.40
			Post-monsoon	271.00	283.10	327.10
	L4	Bisrakh Road	Pre-monsoon	271.45	278.00	332.56
			Post-monsoon	267.00	263.67	301.56
	L5	Bisrakh Road	Pre-monsoon	855.20	883.90	872.30
			Post-monsoon	782.20	867.20	759.90
	L6	Bisrakh Road	Pre-monsoon	6.88	5.21	50.73
			Post-monsoon	16.53	5.09	47.19
	L7	Khera Dharampura	Pre-monsoon	127.61	29.06	134.87
			Post-monsoon	122.80	25.44	125.10
	L8	Bishnuli	Pre-monsoon	340.00	310.00	316.90
			Post-monsoon	325.40	303.70	311.20
	L9	Achheja	Pre-monsoon	315.50	278.10	330.10
			Post-monsoon	302.60	275.90	318.20
Residential Zone	L10	Dairy Maccha	Pre-monsoon	63.90	61.59	73.00
			Post-monsoon	61.12	58.87	65.56
	L11	Dhoom Manikpur	Pre-monsoon	115.40	115.20	189.70
			Post-monsoon	109.50	124.50	182.40
	L12	Dhoom Manikpur	Pre-monsoon	220.45	169.00	231.60
			Post-monsoon	215.80	161.70	228.20
	L13	Badhpura	Pre-monsoon	251.20	150.00	278.40
			Post-monsoon	248.60	148.40	281.20

5.4.5.18 Ammonia

Analytical results of ammonia of waste water samples during study period are presented in Table – 5.4.19. The analytical result revealed that range of ammonia in waste water of study area was 0.27 to 91.8 mg/L. Maximum level of ammonia was found in samples of Badhpura nallah. Analytical results revealed that ammonia level

Table – 5.4.19 Ammonia (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	44.71	46.20	55.34
			Post-monsoon	42.37	45.29	51.57
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	19.39	20.60	24.78
			Post-monsoon	18.71	18.01	22.70
	L3	Bisrakh Road	Pre-monsoon	18.40	19.80	22.76
			Post-monsoon	16.85	19.10	21.42
	L4	Bisrakh Road	Pre-monsoon	12.76	13.00	16.58
			Post-monsoon	11.40	11.60	14.67
	L5	Bisrakh Road	Pre-monsoon	54.21	69.60	76.46
			Post-monsoon	50.33	68.14	66.42
	L6	Bisrakh Road	Pre-monsoon	40.12	32.40	35.44
			Post-monsoon	38.33	30.75	34.67
	L7	Khera Dharampura	Pre-monsoon	36.91	39.90	46.88
			Post-monsoon	32.80	31.30	39.54
	L8	Bishnuli	Pre-monsoon	41.79	37.90	45.52
			Post-monsoon	40.22	36.14	40.24
	L9	Achheja	Pre-monsoon	37.80	34.00	18.36
			Post-monsoon	35.35	32.80	16.81
Residential Zone	L10	Dairy Maccha	Pre-monsoon	38.50	37.20	45.00
			Post-monsoon	36.50	36.99	40.10
	L11	Dhoom Manikpur	Pre-monsoon	11.37	0.43	22.40
			Post-monsoon	3.69	0.44	15.73
	L12	Dhoom Manikpur	Pre-monsoon	0.33	0.27	9.81
			Post-monsoon	0.33	2.43	7.01
	L13	Badhpura	Pre-monsoon	81.58	48.10	91.80
			Post-monsoon	78.59	53.10	79.78

in waste water of agricultural zone was from 42.37 mg/L to 55.34 mg/L). In industrial zone the value of ammonia ranged from 11.4 to 76.46 mg/L with a mean value of 32.58 mg/L. Although mean content of ammonia in three different zone, were somewhat similar, yet maximum mean concentration of ammonia was obtained from agricultural zone (47.58 mg/L) of study area. Fig. 5.4.18 describes the relation between mean concentration of ammonia in groundwater and waste water samples in three different zone of study area.

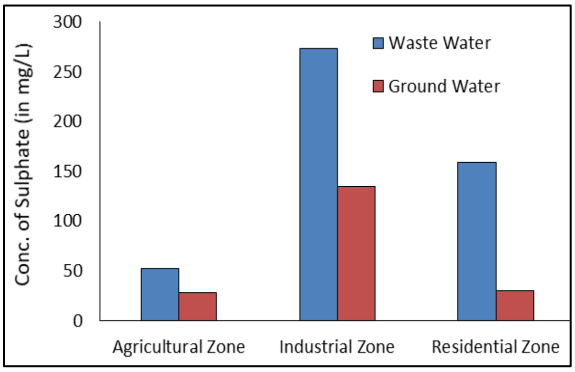


Fig. 5.4.17 Mean Sulphate concentration of Waste water and Groundwater samples in different zone of study area

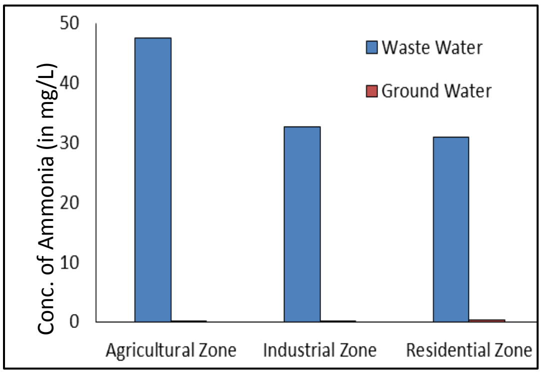


Fig. 5.4.18 Mean Ammonia concentration of Waste water and Groundwater samples in different zone of study area

5.4.6 HEAVY METALS

5.4.6.1 Arsenic

Other than geo-genic source, arsenic can also enters in natural water through various human activities. Arsenic is widely used in fertilizers, treatment of timber, glass industry, and pharmaceuticals industry. Arsenic is also generated in mining process, metal smelting and burning of fossil fuels.

Analytical results of arsenic content in waste water samples during study period are presented in Table – 5.4.20.

The arsenic content of waste water samples varied from 0.846 to 11.692 µg/L with a mean value of 3.878 µg/L during the study period. Maximum arsenic concentration was found in sample collected from Bisrakh Road (L5) and Bishnuli (L8). A chemical factory near the sampling site of waste water sample L5 and a steel pipe manufacturing industry near to the sampling site of L8 was present. Effluents of these factories were responsible for elevated concentration of arsenic in waste water sample. Waste water of agricultural zone of study area showed a mean of 2.148 µg/L of arsenic with a minimum value of 1.365 µg/L and maximum of 2.96 µg/L. Residential zone of study area have arsenic concentration ranged between 0.846 µg/L and 9.08 µg/L. However in industrial zone, waste water arsenic concentration varied from 1.325 to 11.692 µg/L. Industrial zone of study area showed highest mean concentration of arsenic (4.410 µg/L) in waste water samples. According to general standards for discharge of environmental pollutants, arsenic content of waste water should not exceeds the limit of 200 µg/L (Environment Protection Rules, 1986). All the analysed samples were within prescribed limit of arsenic as environmental pollutants. Fig. 5.4.19 explains the relation between mean concentration of arsenic in groundwater and waste water samples in three different zone of study area. There was not a much difference between arsenic content of groundwater and waste water.

Table – 5.4.20 Arsenic (in µg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	2.636	2.96	1.87
			Post-monsoon	2.425	1.365	1.63
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	1.804	1.41	2.006
			Post-monsoon	1.694	1.783	1.686
	L3	Bisrakh Road	Pre-monsoon	1.92	1.61	2.109
			Post-monsoon	1.832	1.621	1.915
	L4	Bisrakh Road	Pre-monsoon	3.145	1.941	2.428
			Post-monsoon	2.905	2.023	2.265
	L5	Bisrakh Road	Pre-monsoon	9.332	4.885	8.845
			Post-monsoon	8.886	5.519	8.456
	L6	Bisrakh Road	Pre-monsoon	4.331	1.853	5.938
			Post-monsoon	4.116	1.802	4.248
	L7	Khera Dharampura	Pre-monsoon	4.328	5.39	6.553
			Post-monsoon	4.176	3.195	5.761
	L8	Bishnuli	Pre-monsoon	10.629	11.634	8.553
			Post-monsoon	11.692	10.443	7.894
	L9	Achheja	Pre-monsoon	2.645	1.362	5.141
			Post-monsoon	2.116	1.325	4.521
Residential Zone	L10	Dairy Maccha	Pre-monsoon	0.951	2.12	2.672
			Post-monsoon	0.846	1.983	2.334
	L11	Dhoom Manikpur	Pre-monsoon	2.829	9.08	4.819
			Post-monsoon	2.691	5.286	4.227
	L12	Dhoom Manikpur	Pre-monsoon	2.438	1.353	3.629
			Post-monsoon	2.268	1.427	3.275
	L13	Badhpura	Pre-monsoon	4.819	1.714	4.661
			Post-monsoon	4.634	3.561	4.325

5.4.6.2 Cadmium

Analytical results of cadmium content of waste water samples during study period are presented in Table – 5.4.21.

The concentration of cadmium ranged from 0.016 to 6.275 µg/L with the mean value of 1.183 µg/L in whole study period. Minimum value of 0.016 µg/L was recorded from waste water sample of Talabpur village of year 2017 and maximum value of 6.275 µg/L was recorded from Dhoom Manikpur nallah (L11) of year 2018.

In agricultural zone cadmium concentration ranged from 0.016 to 0.167 µg/L with a mean of 0.095 µg/L. The cadmium concentration in industrial zone ranged between 0.038 and 1.632 µg/L providing a mean value of 0.583 µg/L. Residential zone of study area also has a wide range of cadmium with a minimum value of 0.102 µg/L and a maximum value of 6.275 µg/L. In industrial zone, waste water of Bishnuli (L8) has minimum concentration of cadmium and Khera Dharampura (L7) station has maximum value. Environment (Protection) Rules, 1986 sets a value of 2000 µg/L cadmium (for inland surface water) and 1000 µg/L cadmium (for public sewers) Fig. 5.4.20 explains the relation between mean concentration of cadmium in groundwater and waste water samples in three different zone of study area. In industrial zone, groundwater cadmium concentration was higher than waste water cadmium concentration. Decreasing order of mean cadmium concentration in different land use pattern- Residential zone (2.655 µg/L) > Industrial zone (0.583 µg/L) > Agricultural zone (0.095 µg/L).

Han et al., (2016) reviewed groundwater contamination near municipal solid waste landfill sites in China and reported cadmium ion concentration of groundwater upto 0.080 mg/L.

Table – 5.4.21 Cadmium (in µg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	0.167	0.016	0.12
			Post-monsoon	0.126	0.019	0.122
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	1.112	0.077	0.278
			Post-monsoon	1.1	0.163	0.217
	L3	Bisrakh Road	Pre-monsoon	0.964	0.606	0.983
			Post-monsoon	0.831	0.616	0.921
	L4	Bisrakh Road	Pre-monsoon	0.712	0.291	0.533
			Post-monsoon	0.728	0.451	0.525
	L5	Bisrakh Road	Pre-monsoon	0.755	0.928	0.831
			Post-monsoon	0.621	0.781	0.755
	L6	Bisrakh Road	Pre-monsoon	0.492	0.822	0.375
			Post-monsoon	0.415	0.754	0.237
	L7	Khera Dharampura	Pre-monsoon	1.632	0.195	1.312
			Post-monsoon	1.113	0.146	1.162
	L8	Bishnuli	Pre-monsoon	0.068	0.051	1.228
			Post-monsoon	0.045	0.038	1.007
	L9	Achheja	Pre-monsoon	0.461	0.079	0.085
			Post-monsoon	0.381	0.062	0.043
Residential Zone	L10	Dairy Maccha	Pre-monsoon	1.866	1.984	2.152
			Post-monsoon	1.812	1.751	1.792
	L11	Dhoom Manikpur	Pre-monsoon	4.338	3.121	6.275
			Post-monsoon	4.529	3.426	2.698
	L12	Dhoom Manikpur	Pre-monsoon	2.416	0.102	2.937
			Post-monsoon	2.271	0.196	2.644
	L13	Badhpura	Pre-monsoon	3.517	2.552	2.819
			Post-monsoon	3.227	2.372	2.928

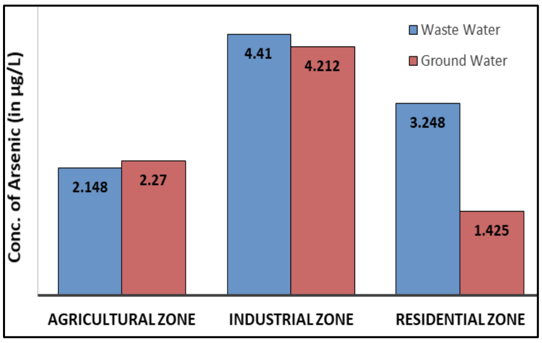


Fig. 5.4.19 Mean Arsenic concentration of Waste water and Groundwater samples in different zone of study area

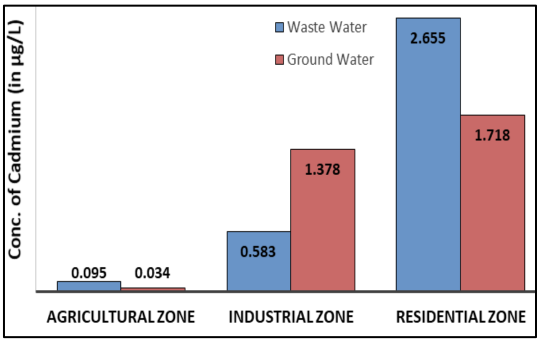


Fig. 5.4.20 Mean Cadmium concentration of Waste water and Groundwater samples in different zone of study area

5.4.6.3 Chromium

Chromium is an ingredient of stainless steel and other alloys. It is used in leather tanning, explosive, ceramics, paint pigments, photography and wood preservation (Chatopadhyay, 1973). It is used in industries for the manufacturing of steel, jet engines, tools, paints, photography, electronic cells, rubber goods and matchstics (Kudesia & Kudesia, 1998). Chromium is sparingly soluble in water however it is present in industrial discharge, waste water of mining and household activities. Chromium uptake by submerged rice paddies from the addition of municipal solid waste compost was studied by Bhattacharyya et al., 2005.

Analytical results of chromium content of waste water samples during study period are presented in Table – 5.4.22. Obtained range of chromium in analysed waste water samples was from 6.481 to 42.554 µg/L. The minimum concentration of chromium was obtained from Dhoom Manikpur nallah (L11) in year 2018 and maximum concentration was found in samples of Bisrakh Road (L5) in year 2018. The analysed range of chromium in three different zone of study area was; 8.711 to 9.164 µg/L (in agricultural waste water), 7.431 to 42.554 µg/L (in industrial waste water) and 6.481 to 27.84 µg/L (in domestic waste water). Maximum mean value of chromium was obtained from industrial zone of study area. Increasing order of mean chromium concentration in three different zone study area was – 8.944 µg/L (agricultural zone) < 14.669 µg/L (residential zone) < 16.041 µg/L (industrial zone). Environment (Protection) Rules, 1986 sets a value of 2000 µg/L chromium in effluent discharge. All the analysed samples were well below the standard chromium effluent discharge value given by environment protection. Higher quantity of chromium was found in samples of Bisrakh Road (L5) and Badhpura nallah (L13).

Fig. 5.4.21 explains the relation between mean concentration of chromium in groundwater and waste water samples in three different zone of study area. There was not a great difference in chromium value in groundwater and waste water, it shows leaching of metal from waste water to ground aquifers. Tariq et al., (2008) studied effects of effluent of tanning industries on groundwater quality of Kasur city of Pakistan. They reported chromium contamination (mean; 2.12 mg/L0 of groundwater due to tanning effluent. Similar type of studies on impacts of tannery effluents on groundwater quality were done by many researchers (Brindha & Elango, 2012; Mangal et al., 2013; Wosnie & Wondie, 2014; Saritha & Chockalingam, 2018).

Table – 5.4.22 Chromium (in μg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	9.164	9.07	8.823
			Post-monsoon	9.031	8.867	8.711
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	15.43	10.56	12.684
			Post-monsoon	15.345	10.704	12.571
	L3	Bisrakh Road	Pre-monsoon	15.735	10.73	12.324
			Post-monsoon	15.457	14.923	19.454
	L4	Bisrakh Road	Pre-monsoon	18.227	9.168	12.719
			Post-monsoon	17.964	12.752	11.842
	L5	Bisrakh Road	Pre-monsoon	38.186	42.175	42.554
			Post-monsoon	36.589	40.586	40.328
	L6	Bisrakh Road	Pre-monsoon	11.627	12.054	13.418
			Post-monsoon	10.885	9.426	13.187
	L7	Khera Dharampura	Pre-monsoon	15.552	10.382	18.972
			Post-monsoon	16.518	14.824	17.336
	L8	Bishnuli	Pre-monsoon	7.843	8.228	8.892
			Post-monsoon	7.431	8.681	9.226
	L9	Achheja	Pre-monsoon	10.523	12.864	9.879
			Post-monsoon	10.428	13.006	9.775
Residential Zone	L10	Dairy Maccha	Pre-monsoon	11.517	10.975	12.869
			Post-monsoon	11.221	11.142	12.628
	L11	Dhoom Manikpur	Pre-monsoon	8.314	10.318	7.672
			Post-monsoon	7.967	8.271	6.481
	L12	Dhoom Manikpur	Pre-monsoon	12.881	27.84	18.285
			Post-monsoon	10.279	26.296	15.552
	L13	Badhpura	Pre-monsoon	25.618	16.417	19.289
			Post-monsoon	23.718	18.287	18.218

5.4.6.4 Copper

Copper is extensively used metal in the industries next to iron and aluminum (Kannan, 1991). It is extensively used in paints, ceramics, pesticides, and in the chemical industry. The source of copper in water is mostly due to corrosion of copper alloys in pipe fittings. Copper is the second most toxic metal for fishes, invertebrates and aquatic plants.

Analytical results of copper content of waste water samples during study period are presented in Table – 5.4.23.

Table – 5.4.23 Copper (in µg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	4.38	6.05	8.732
			Post-monsoon	4.414	3.642	8.727
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	6.331	2.45	2.964
			Post-monsoon	6.54	2.218	2.971
	L3	Bisrakh Road	Pre-monsoon	12.608	13.07	14.221
			Post-monsoon	13.107	10.353	12.746
	L4	Bisrakh Road	Pre-monsoon	11.836	15.889	16.216
			Post-monsoon	12.554	17.135	16.118
	L5	Bisrakh Road	Pre-monsoon	4.446	6.026	3.426
			Post-monsoon	5.631	5.132	3.957
	L6	Bisrakh Road	Pre-monsoon	7.227	15.53	8.531
			Post-monsoon	7.356	16.432	8.742
	L7	Khera Dharampura	Pre-monsoon	9.486	4.286	7.415
			Post-monsoon	8.741	6.437	7.826
	L8	Bishnuli	Pre-monsoon	8.848	7.96	9.334
			Post-monsoon	9.132	8.658	9.544
	L9	Achheja	Pre-monsoon	4.143	3.568	5.102
			Post-monsoon	3.981	3.237	5.007
Residential Zone	L10	Dairy Maccha	Pre-monsoon	6.451	5.552	8.218
			Post-monsoon	6.378	4.981	7.546
	L11	Dhoom Manikpur	Pre-monsoon	8.381	5.48	5.112
			Post-monsoon	8.793	5.491	3.965
	L12	Dhoom Manikpur	Pre-monsoon	6.281	2.034	4.297
			Post-monsoon	6.719	1.934	4.738
	L13	Badhpura	Pre-monsoon	4.186	3.771	5.283
			Post-monsoon	2.985	3.829	6.117

Obtained range of copper concentration in analysed waste water samples was from 1.934 µg/L (in waste water of Dhoom Manikpur nallah L12) to 17.135 µg/L (in Bisrakh Road samples L4). In agricultural waste water, copper concentration ranged from 3.642 to 8.732 µg/L whereas in industrial waste water, it ranged from 2.218 to 17.135 µg/L. In waste water of various nallahs in residential area, copper concentration varied from 1.934 to 8.793 µg/L. Relative order of mean copper concentration in various zone was; 8.426 (Industrial area) > 5.991 (agricultural area) > 5.355 (residential area). Higher concentration of copper was obtained in waste water samples collected from Bisrakh Road (L3 & L4). Fig. 5.4.22 explains the relation between mean concentration of copper in groundwater and waste water samples in three different zone of study area.

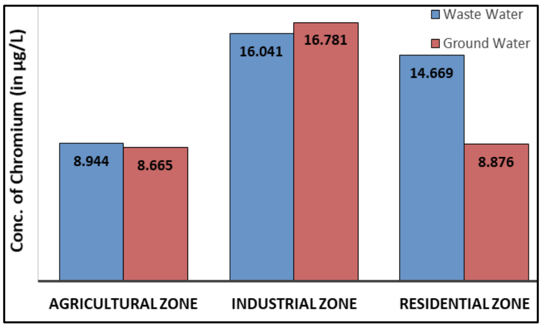


Fig. 5.4.21 Mean Chromium concentration of Waste water and Groundwater samples in different zone of study area

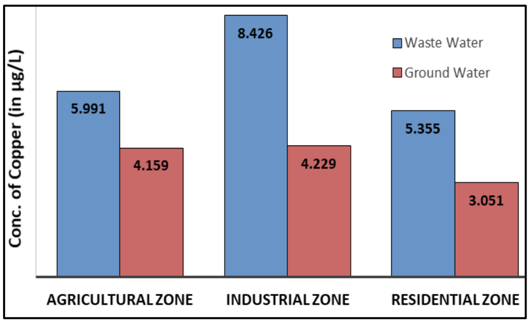


Fig. 5.4.22 Mean Copper concentration of Waste water and Groundwater samples in different zone of study area

5.4.6.5 Nickel

Nickel and its compounds are widely used in industries of magnets, alloying of elements, coatings of kitchen utensils, catalyst and batteries. It is an important component of stainless steel; a common brand contains 8% Ni and 18% Cr. Stainless steel is the most widely used nickel alloy (Sittig, 1979). It finds use as a catalyst and as a mordant in ceramic glasses (Adriano, 1986). Nickel salts are easily dissolve in water and hence cause the pollution through industrial or municipal waste discharge (Ensink et al., 2007).

Analytical results of nickel content of waste water samples during study period are presented in Table – 5.4.24.

The content of nickel varied from 0.532 to 15.458 µg/L with a mean value of 7.806 µg/L during the study period. Waste water of agricultural zone of study area showed a mean of 6.333 µg/L of nickel with a minimum value of 2.31 µg/L and maximum of 7.569 µg/L.

Table – 5.4.24 Nickel (in µg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	7.245	2.31	7.569
			Post-monsoon	7.163	6.278	7.435
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	14.419	11.628	12.975
			Post-monsoon	14.221	12.108	12.416
	L3	Bisrakh Road	Pre-monsoon	14.886	14.526	11.634
			Post-monsoon	14.116	14.589	11.664
	L4	Bisrakh Road	Pre-monsoon	9.665	12.724	15.458
			Post-monsoon	8.165	12.118	14.892
	L5	Bisrakh Road	Pre-monsoon	4.724	10.382	7.889
			Post-monsoon	4.155	9.742	7.629
	L6	Bisrakh Road	Pre-monsoon	8.416	8.769	9.628
			Post-monsoon	8.241	8.515	9.475
	L7	Khera Dharampura	Pre-monsoon	10.413	9.975	14.557
			Post-monsoon	10.115	10.236	13.886
	L8	Bishnuli	Pre-monsoon	5.542	6.932	6.493
			Post-monsoon	5.621	6.749	7.224
	L9	Achheja	Pre-monsoon	0.544	0.583	0.558
			Post-monsoon	0.532	0.561	0.538
Residential Zone	L10	Dairy Maccha	Pre-monsoon	13.391	10.561	10.571
			Post-monsoon	9.446	10.217	10.335
	L11	Dhoom Manikpur	Pre-monsoon	5.167	3.716	2.819
			Post-monsoon	4.293	3.286	2.252
	L12	Dhoom Manikpur	Pre-monsoon	3.664	3.452	4.618
			Post-monsoon	3.281	2.995	4.839
	L13	Badhpura	Pre-monsoon	3.293	3.817	3.553
			Post-monsoon	3.117	3.621	3.728

Residential zone of study area have nickel concentration ranged between 2.252 µg/L and 13.391 µg/L. However in industrial zone, waste water nickel concentration varied from 0.532 to 15.458 µg/L. Industrial zone of study area showed highest mean concentration of nickel (9.184 µg/L) in waste water samples. All the analysed waste water samples were within the standard effluent discharge of nickel (3000 µg/L) laid by Environment Protection Rules (1986). Fig. 5.4.23 explains the relation between mean concentration of nickel in groundwater and waste water samples in three different zone of study area.

5.4.6.6 Lead

Lead is required for manufacturing of lead-acid batteries, ammunition, solder, piping, pigments, alloys and insecticides. The organo lead compounds; $(CH_3CH_2)_4Pb$, $(CH_3)_4Pb$ are mixed with petrol as antiknock and lubricating agents. Now-a-days, use of unleaded petrol in developed countries has decreased the lead emission markedly. Excess amount of lead is found in effluent coming from various mechanical workshops, combustion of fossil fuels (Katariya, 1994) and in municipal waste water of the city (Harrison & Laxen, 1984). Lead particles, present in automobile exhaust also contributes lead to our environment (Agrawal et al., 1978; Pophali et al., 1990). Tap waters may be lead contaminated due to lead pipes in water distribution system.

Analytical results of lead content of waste water samples during study period are presented in Table – 5.4.25.

Lead content of waste water of study area was recorded in a great variation. The minimum lead (1.985 µg/L) was recorded from Bisrakh Road (L4) in post-monsoon season of year 2017 while maximum (33.88 µg/L) was recorded from Bisrakh Road (L5) in pre-monsoon sample of year 2017. Such type of anomaly in results showed some local source of lead pollution near to sampling site of L5. Effluent of paper industry, situated at Bisrakh Road can be a possible source of lead content in waste water. Lead of analysed waste water samples in agricultural zone ranged from 2.729 µg/L to 3.58 µg/L. Lead of industrial waste water were found to vary from 1.985 to 33.88 µg/L. Lead content of domestic waste water was recorded minimum 2.422 µg/L in Dhoom Manikpur nallah (L11) and maximum 5.291 µg/L in another nallah of same village (L12). Fig. 5.4.24 explains the relation between mean concentration of lead in groundwater and waste water samples in three different zone of study area. In agricultural area, mean lead content in groundwater and waste water was nearly same.

Han et al., (2016) reviewed groundwater contamination near municipal solid waste landfill sites in China and reported lead ion concentration of groundwater upto 1.340 mg/L. Similar kind of study was done by Olaoye & Oladeji, (2015) and reported average lead content of 1.18 mg/L in groundwater of Ibadan in Nigeria.

Table – 5.4.25 Lead (in µg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	3.478	3.58	2.84
			Post-monsoon	3.402	3.231	2.729
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	4.416	2.4	2.186
			Post-monsoon	4.118	2.012	2.002
	L3	Bisrakh Road	Pre-monsoon	3.229	2.5	2.732
			Post-monsoon	2.327	2.115	2.241
	L4	Bisrakh Road	Pre-monsoon	4.138	2.046	5.332
			Post-monsoon	4.116	1.985	4.681
	L5	Bisrakh Road	Pre-monsoon	6.118	33.88	15.468
			Post-monsoon	5.885	31.517	14.328
	L6	Bisrakh Road	Pre-monsoon	5.418	3.717	3.911
			Post-monsoon	4.933	3.518	3.736
	L7	Khera Dharampura	Pre-monsoon	8.524	5.776	6.529
			Post-monsoon	8.197	5.221	5.772
	L8	Bishnuli	Pre-monsoon	5.893	6.489	5.931
			Post-monsoon	5.614	5.415	6.118
	L9	Achheja	Pre-monsoon	3.427	3.628	3.429
			Post-monsoon	3.177	3.28	3.323
Residential Zone	L10	Dairy Maccha	Pre-monsoon	3.176	4.275	4.781
			Post-monsoon	3.829	4.128	4.345
	L11	Dhoom Manikpur	Pre-monsoon	5.291	2.422	4.228
			Post-monsoon	4.187	3.451	4.141
	L12	Dhoom Manikpur	Pre-monsoon	5.291	3.872	4.223
			Post-monsoon	5.118	3.752	4.118
	L13	Badhpura	Pre-monsoon	2.867	3.26	3.442
			Post-monsoon	2.561	2.972	3.175

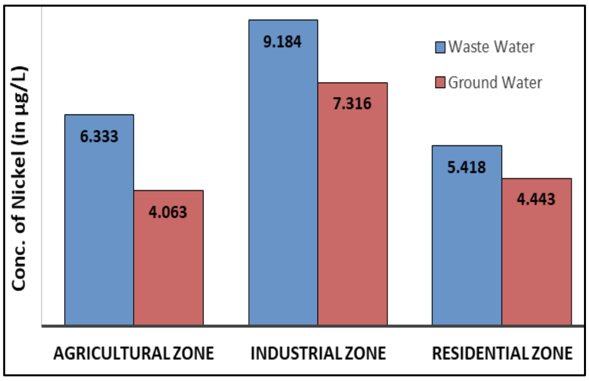


Fig. 5.4.23 Mean Nickel concentration of Waste water and Groundwater samples in different zone of study area

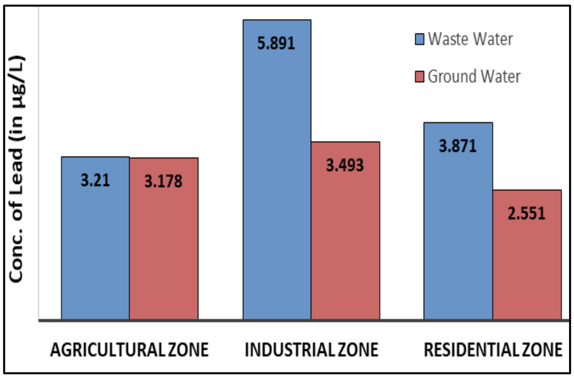


Fig. 5.4.24 Mean Lead concentration of Waste water and Groundwater samples in different zone of study area

5.4.6.7 Iron

Iron is widely used in alloys like steel. The occurrence of iron in waste waters can be related to effluent of mining, leachates originated from landfill sites, sewage water and iron-steel industries. The cause of the presence of iron in domestic waste water are the use of cast iron and steel pipes for water drainage (Cox, 1964).

Analytical results of iron content of waste water samples during study period are presented in Table – 5.4.26.

Table – 5.4.26 Iron (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	0.381	0.316	0.257
			Post-monsoon	0.383	0.304	0.267
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	0.121	0.105	0.212
			Post-monsoon	0.135	0.104	0.21
	L3	Bisrakh Road	Pre-monsoon	0.986	0.734	0.751
			Post-monsoon	1.002	0.622	0.642
	L4	Bisrakh Road	Pre-monsoon	1.527	1.243	2.862
			Post-monsoon	1.862	1.443	3.112
	L5	Bisrakh Road	Pre-monsoon	0.832	1.502	1.332
			Post-monsoon	0.964	1.114	1.194
	L6	Bisrakh Road	Pre-monsoon	0.416	0.132	0.403
			Post-monsoon	0.488	0.286	0.512
	L7	Khera Dharampura	Pre-monsoon	0.376	0.581	0.497
			Post-monsoon	0.341	0.529	0.441
	L8	Bishnuli	Pre-monsoon	0.311	0.292	0.462
			Post-monsoon	0.307	0.221	0.373
	L9	Achheja	Pre-monsoon	0.284	0.235	0.468
			Post-monsoon	0.297	0.181	0.341
Residential Zone	L10	Dairy Maccha	Pre-monsoon	0.215	0.211	0.472
			Post-monsoon	0.236	0.215	0.468
	L11	Dhoom Manikpur	Pre-monsoon	0.273	0.252	0.385
			Post-monsoon	0.286	0.282	0.396
	L12	Dhoom Manikpur	Pre-monsoon	0.352	0.198	0.261
			Post-monsoon	0.276	0.297	0.195
	L13	Badhpura	Pre-monsoon	0.286	0.635	0.715
			Post-monsoon	0.528	0.612	0.733

During the period under study, iron content of waste water varied from 0.104 to 3.112 mg/L. Both minimum and maximum limit of iron were obtained from the samples taken from Bisrakh Road (L2 & L5 respectively). In agricultural waste water, iron content ranged from 0.257 to 0.383 mg/L with a mean value of 318 mg/L. In municipal waste water, mean value of iron was 0.366 mg/L (ranged from 0.195 to 0.733 mg/L). Industrial waste water showed maximum mean value of iron which was 0.696 mg/L). Decreasing order of mean iron concentration in waste water collected from various zone was 0.696 mg/L (industrial) > 0.366 mg/L (residential) > 0.318 mg/L (agricultural).

Fig. 5.4.25 explains the relation between mean concentration of iron in groundwater and waste water samples in three different zone of study area. In agricultural area, mean iron concentration in groundwater was higher than waste water. It reveals that in this region, groundwater was not greatly affected by leaching of metal but have geological origin. High iron content (11.16 to 12.04 mg/L) was analysed in leachate samples collected from Mavallipura landfill site in Bangalore (Naveen et al., 2016).

5.4.6.8 Zinc

Zinc based alloys (brass & bronze) are used in batteries, construction materials, fungicides, pigments and in printing processes. It is also used for protective coating on iron, steel, brass and alloys. The source of zinc in water may be mostly due to industrial activities like electroplating units (Stumm & Lee, 1960), galvanizing plant effluents (Pandey & Seth,1983), fly ash (Kannan, 1991) etc. The deterioration of galvanized iron and zincification of brass are the reason for the presence of Zinc in the domestic water supply.

Analytical results of zinc content of waste water samples during study period are presented in Table – 5.4.27.

Zinc content of waste water of study area were recorded in a great variation. The minimum zinc (0.0092 mg/L) was recorded from Dairy Maccha nallah in post-monsoon sample of year 2016 while maximum (2.9376 mg/L) was recorded from Bisrakh Road (L6) in post-monsoon sample of year 2018. Zinc of analysed waste water samples in agricultural zone ranged from 0.031 mg/L to 0.0614 mg/L. Zinc of industrial waste water were found to vary from 0.0428 mg/L to 2.9376 mg/L. Zinc content of domestic waste water was recorded minimum 0.0092 mg/L in Dairy Maccha nallah and maximum 0.07891 mg/L in Dhoom Manikpur Nallah. Environment (Protection) Rules, 1986 gives a value of 5 mg/L of zinc for inland surface water and 15 mg/L of zinc for public sewers. All the analysed waste water samples were under the standard limits of effluents.

Fig. 5.4.26 describes the relation between mean concentration of zinc in groundwater and waste water samples in three different zone of study area.

Table – 5.4.27 Zinc (in mg/L) of Waste Water samples during Study period (2016 – 2018)

Zone	Waste Water Sample No.	Water Quality Station	Season	2016	2017	2018
Agricultural Zone	L1	Talabpur	Pre-monsoon	0.0426	0.0415	61.40
			Post-monsoon	0.0378	0.031	0.0452
Industrial Zone	L2	Bisrakh Road	Pre-monsoon	0.0988	0.0776	0.0428
			Post-monsoon	0.0975	0.1038	0.1103
	L3	Bisrakh Road	Pre-monsoon	0.118	0.0798	0.1095
			Post-monsoon	0.106	0.104	0.1401
	L4	Bisrakh Road	Pre-monsoon	0.1672	0.0806	0.121
			Post-monsoon	0.148	0.1008	0.0972
	L5	Bisrakh Road	Pre-monsoon	1.523	1.636	0.0885
			Post-monsoon	1.458	1.435	1.892
	L6	Bisrakh Road	Pre-monsoon	2.7325	2.6732	1.746
			Post-monsoon	2.422	2.5581	2.9376
	L7	Khera Dharampura	Pre-monsoon	0.2243	0.2594	2.7352
			Post-monsoon	0.2251	0.2557	0.2671
	L8	Bishnuli	Pre-monsoon	0.1247	0.0953	0.2785
			Post-monsoon	0.1212	0.0792	0.0462
	L9	Achheja	Pre-monsoon	0.1096	0.1129	0.0455
			Post-monsoon	0.1055	0.0998	0.1072
Residential Zone	L10	Dairy Maccha	Pre-monsoon	0.012	0.0126	0.1021
			Post-monsoon	0.0092	0.0095	0.0135
	L11	Dhoom Manikpur	Pre-monsoon	0.7891	0.0149	0.0118
			Post-monsoon	0.7328	0.6832	0.7732
	L12	Dhoom Manikpur	Pre-monsoon	0.7781	0.1334	0.7714
			Post-monsoon	0.7732	0.1292	0.6438
	L13	Badhpura	Pre-monsoon	0.0118	0.0106	0.6391
			Post-monsoon	0.0192	0.0109	0.1131

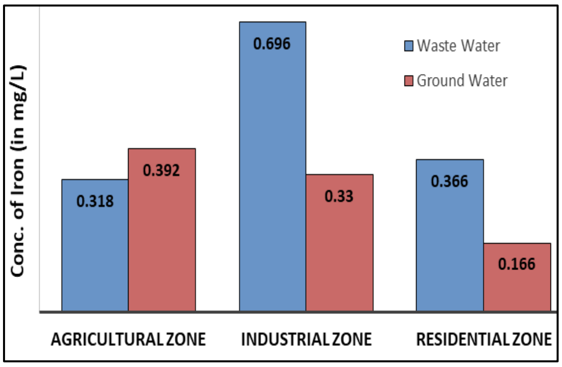


Fig. 5.4.25 Mean Iron concentration of Waste water and Groundwater samples in different zone of study area

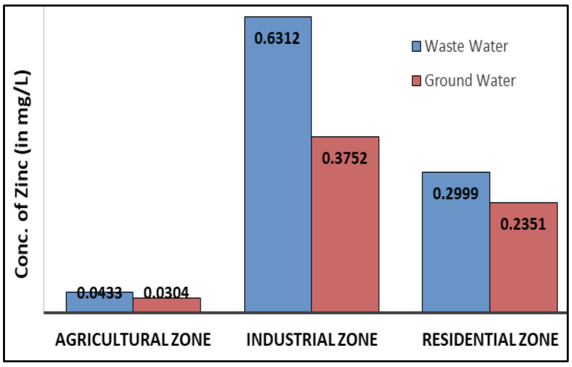


Fig. 5.4.26 Mean Zinc concentration of Waste water and Groundwater samples in different zone of study area

SUMMARY

From the above discussion it is clear that the first waste water sample L1, which contained agricultural runoff, showed high content of ammonia, potassium, nitrate and iron. Mean value of ammonia was found maximum in agricultural waste water.

In industrial zone, waste water sample L3 & L5 were highly polluted. Mean value of pH, conductivity, total dissolved solids, calcium, sodium, potassium, boron, total hardness, chloride, nitrate, sulphate and analysed metals (As, Cr, Cu, Pb, Ni, Fe & Zn) were high in waste water of industrial area. A pond like structure and sand bed was present near to source of Sample L5. Both factors favor the greater percolation of wastewater into the ground aquifer hence affects ground water quality up to a great extent.

Mean value of turbidity, magnesium, total alkalinity, fluoride, nitrite, phosphate and cadmium were maximum in domestic waste water. Waste water samples L10, L11, L12 & L13 were slightly polluted but had higher impact on groundwater due to volume of domestic waste water was very high. From comparing the analytical results of groundwater and waste water, it was proved that leaching of various ions from contaminated water into soil layers was prevalent in study area.

5.5.1 INTRODUCTION

Water quality index (WQI) system is a widely used technique to show the quality of water that offers a numeric, easy to understand and reproducible number which signifies the changes in the important parameters of water (Brown et al., 1972). It can be expressed as a mathematical figure which demonstrates the combine effect of characteristic physico-chemical and biological parameters on quality of water. It is an effective medium for evaluation of groundwater quality as it summarize the huge water quality data into a simple numerical score (Mohebbi et al., 2013). Water quality index is the only tool by which the highly multi-attribute and multi-variate concept of water quality can be conveyed to persons in the form of a numeric score. After the development of water quality indices in a particular area, it can be applied to examine the anthropogenic and environmental factors that affect the quality of water and also help policy makers to decide strategy in that area.

Initially in 1965, Horton proposed that different physical, chemical and biological parameters can be incorporated into an overall water quality index. Brown et al., (1970) put forward a general way for the computation of water quality index. Walski & Parker, (1974) used an exponential function to illustrate the sub-indices of various quality variables. Deininger extended it for the Scottish Development Department, (1975). The sub-index of each physico-chemical parameter was combined into Pearson type 3-distribution function by Landwehr, (1979). The exponential expression was revised by Bhargava, (1987). A power function for each of sub-index was used by Dinius, (1987). Subsequently various improvements have been done by various scientists to calculate water quality index (Stambuk-Giljanovic, 1999; Swamee & Tyagi, 2000; Harrison et al., 2000; Faisal et al., 2003; Said et al., 2004; Liou et al., 2004). The different water quality indices are used by different countries e.g. US National Sanitation Foundation Water Quality index (NSF WQI), British Columbia Water Quality Index (BCWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI), Nemerow and Sumitomo's Pollution Index, Oregon Water Quality Index (OWQI), Weighted Arithmetic Water Quality Index (WAWQI) etc. (Nemerow & Sumitomo, 1970; Cude, 2001; Abbasi, 2002; Kannel et al., 2007; Hurley et al., 2012).

Basically formulation of water quality index is done in four steps. First step is selection of parameters which majorly affect the quality of water. In second step each physico-chemical parameter is converted into an equal scale of unit. Third step (not essential to all methods) is assignment of weightages to each of the parameter and last fourth step is combination of sub-indices for each parameter into a final index value (Abbasi & Abbasi, 2012).

Groundwater is the major source of irrigation and drinking water in current study area. Three methods of calculating water quality index were used to develop WQI of groundwater in current study area- Weighted Arithmetic Water Quality Index (WAWQI), Groundwater Quality Index (GWQI) and Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI).

5.5.2 WEIGHTED ARITHMETIC WATER QUALITY INDEX (WAWQI)

Weighted arithmetic water quality index method is used to dictate the quality of water by using selected water quality parameters. The potability of water was analysed by several researchers by this method (Rao et al., 2010; Balan et al., 2012; Gupta & Misra, 2016; Harshan et al., 2017). Calculation of WAWQI was carried out in this work by Brown's method (1972). Calculation of WAWQI was done in four steps-

Step 1- First unit weight (W_n) of nth water quality parameter was calculated. Unit weight W_n is inversely proportional to standard value of nth water quality parameter (S_n).

$$W_n = k / S_n \quad (1)$$

Where k = proportionality constant and can be determined by-

$$k = 1 / \sum_{i=1}^{n} 1/S_n \quad (2)$$

Step 2- Quality rating (Q_n) of nth water quality parameter for all the selected parameters was calculated.

$$Q_n = [(V_{actual} - V_{ideal}) / (S_{standard} - V_{ideal})] \times 100 \quad (3)$$

V_{actual} = Actual value of nth water quality parameter for each sample,

V_{ideal} = Ideal value for nth parameter in pure water. (V_{ideal} = 0 for all parameters except pH = 7, for DO =14.6 mg/L),

$S_{standard}$ = Standard value of n^{th} water quality parameter.

Step 3- Finally overall WAWQI was calculated by combining unit weight (W_n) and quality rating (Q_n):

$$WAWQI = Q_n W_n / W_n \quad (4)$$

In the current study, the water quality indices of groundwater samples were calculated by selecting 13 parameters (pH, TDS, turbidity, TH, TA, Ca^{2+}, Mg^{2+}, B, Cl^-, F^-, SO_4^{2-}, NO_3^- and NH_3). The basis of selection of these parameters was that these are the major cations & anions present in groundwater which affect the potability of water. Groundwater is the main source of drinking water in the study area hence concentration of these cations & anions were chosen for calculating water quality index. A further drinking water quality standards of BIS 10500, 2012, were used for standardization of parameters. Finally by aggregating sub-indices for individual parameter, overall water quality index was calculated for each sample. By comparing the water quality index of each sample with standard water quality rating, the characteristic quality of groundwater was obtained (Table – 4.9). Based on standard method of calculation of weighted arithmetic water quality index, WAWQI values of groundwater samples collected during study period (pre and post monsoon season of year 2016, 2017 and 2018) are given in Table – 5.5.1.

Water quality index calculated from WAWQI method ranged from 19 (in post-monsoon sample of year 2016 at Bishnuli water quality station) to 914 (in pre-monsoon sample of year 2018 at Dhoom Manikpur water quality station). During 2016, WAWQI value of groundwater ranged from 19 to 812, in 2017 its value varied from 21 to 804 while in 2018 WAWQI value was from 29 to 914. Out of total collected samples, only 5 samples (pre and post- monsoon sample of year 2017 at Duryai station, post-monsoon sample of year 2017 at Bisrakh Road station and post-monsoon sample of year 2016 & 2017 at Bishnuli station) have excellent type of water quality with WAWQI value from 0 to 25. Nearly 30% of total collected samples have good water quality. 14% of samples have WAWQI value between 51 and 75 and hence have poor quality of water for drinking purpose. These samples were majorly collected from industrial zone of study area.

Table – 5.5.1 Weighted arithmetic water quality index (WAWQI) of Groundwater Samples during study period

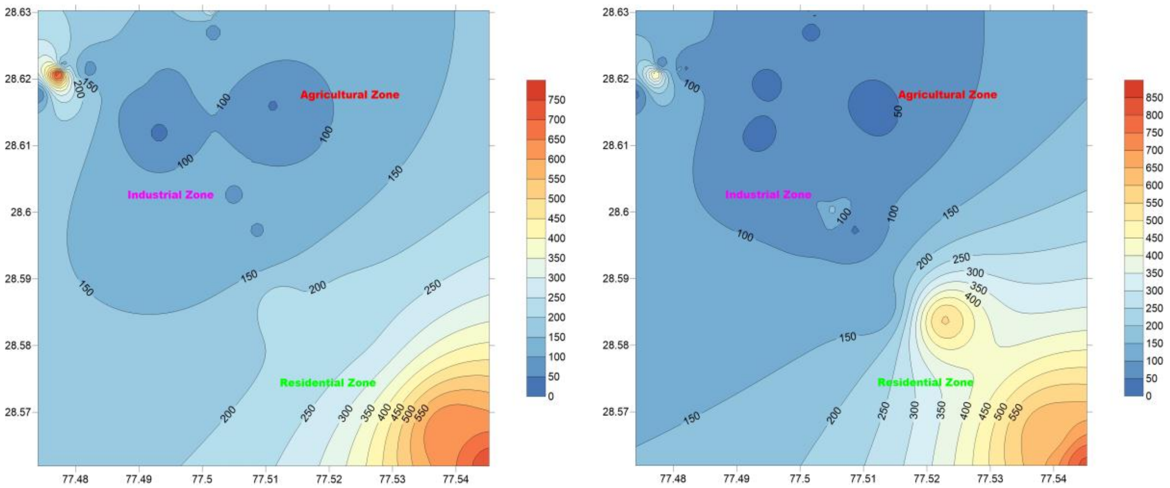
Sample No.	Water Quality Station	WAWQI					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
S1	Duryai	330	116	255	203	195	93
S2	Duryai	51	34	44	47	96	58
S3	Duryai	79	40	25	24	80	42
S4	Talabpur	87	33	35	28	75	35
S5	Bisrakh Road	123	106	40	86	39	116
S6	Bisrakh Road	57	38	56	87	76	88
S7	Bisrakh Road	774	483	495	329	544	312
S8	Bisrakh Road	109	42	30	26	78	57
S9	Bisrakh Road	53	36	57	23	94	74
S10	Khera Dharampura	61	91	109	72	110	43
S11	Bishnuli	39	19	39	21	73	36
S12	Achheja	148	78	58	102	167	149
S13	Achheja	104	164	39	131	76	183
S14	Dujana	93	72	102	47	184	81
S15	Dujana	100	81	32	28	66	31
S16	Dujana	47	28	30	26	50	30
S17	Dujana	55	36	54	36	42	33
S18	Badalpur	97	46	47	28	52	29
S19	Sadopur	223	106	41	86	299	184
S20	Dairy Maccha	241	555	114	225	582	176
S21	Dhoom Manikpur	650	632	706	641	914	865
S22	Badhpura	733	812	804	725	553	411

Results of study revealed that 14.4% of samples have WAWQI value between 76 and 100 (very poor type of water) and 37.9% of samples have WAWQI value greater than 100 (unsuitable for drinking). Most of the samples collected from residential zone of study area have WAWQI value above 100.

Spatial distribution map of WAWQI value, throughout the study period, indicates that groundwater quality of study area was affected from the percolation of domestic waste water (Fig. 5.5.1). It is also observed that WAWQI value decreased in post-monsoon season due to recharging of ground aquifers. Improvement in water quality indicates lowering of ionic concentration in groundwater.

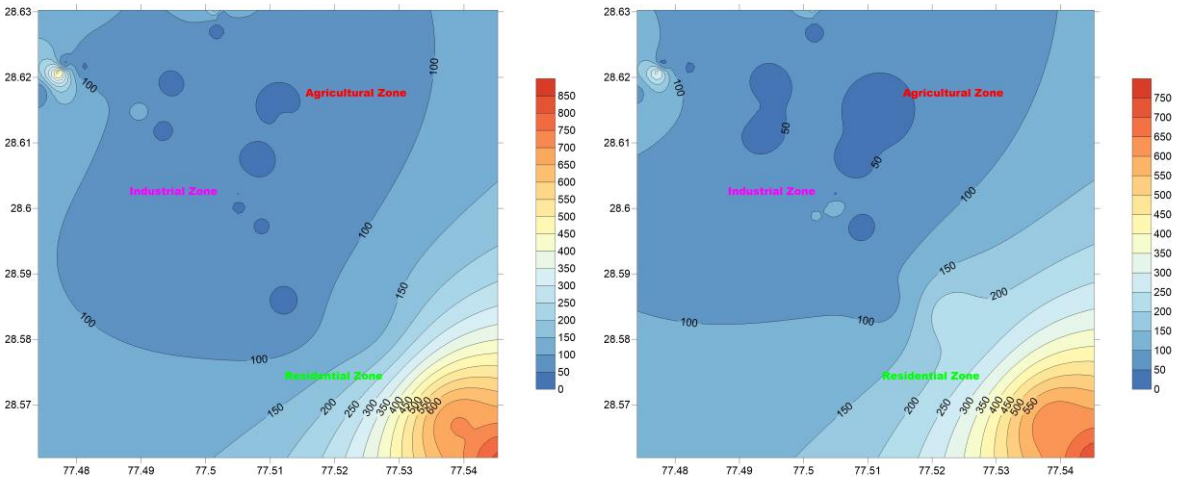
Percentage representation of WAWQI classification (Fig. 5.5.2) shows that in year 2016, none of the sample in pre-monsoon season showed excellent quality of water but in post-monsoon season 4.5% of samples have excellent water. Similarly percentage of unsuitable quality of groundwater samples decreased in post-monsoon season (from 50% to 36.4%). In year 2017, a slight variation in groundwater quality was observed from pre-monsoon to post-monsoon season. Percentage of excellent quality of groundwater samples increased (from 4.5% to 13.6%) but percentage of samples having unsuitable quality of water remained same (Fig. 5.5.3). In year 2018, percent sample having good quality of water increased in post-monsoon season from 13.6 to 36.4%. Results of study also showed that percentage of samples with poor, very poor and unsuitable quality of water decreased in post-monsoon season (from 18.2 to 13.6%, from 27.3 to 13.6% and from 40.9 to 36.4% respectively) (Fig. 5.5.4).

Groundwater quality of Chunnakam and Jaffna Town of Sri Lanka was analysed by Harshan et al., 2017. They reported that WAWQI value ranged from 1.7 to 75.5 in Chunnakam town and from 1.2 to 64.6 in Jaffna town. Gupta & Mishra, 2016 analysed the potability of groundwater of Jhajjar district of Haryana and found that groundwater is unsuitable for drinking purpose as WAWQI value of all the analysed samples was above 100.



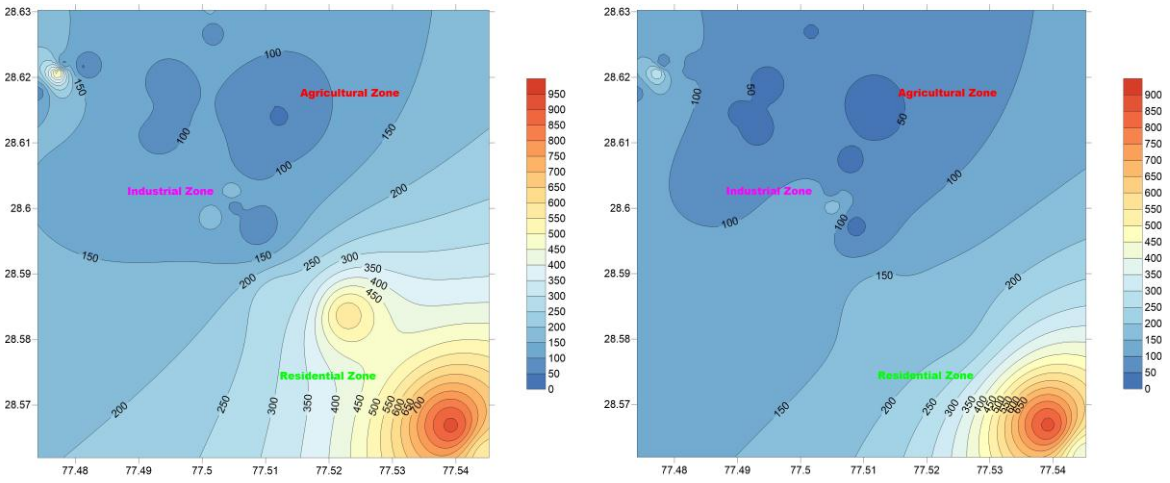
2016 (Pre-monsoon)

2016 (Post-monsoon)



2017 (Pre-monsoon)

2017 (Post-monsoon)



2018 (Pre-monsoon)

2018 (Post-monsoon)

Fig. 5.5.1 Spatial Distribution of WAWQI in Groundwater Samples of study area during study period (2016-2018)

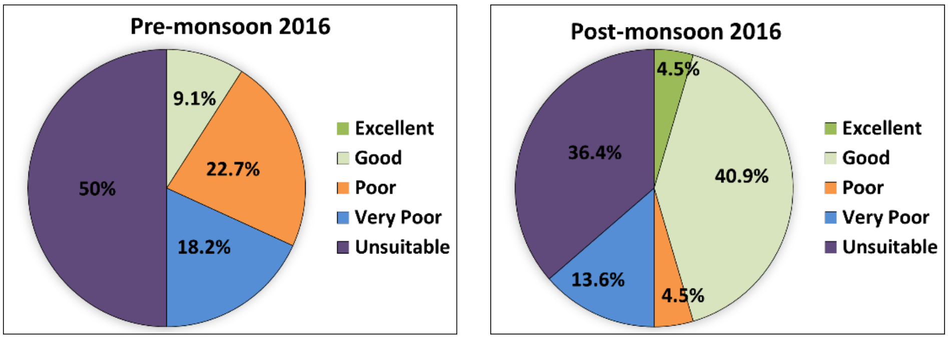


Fig. 5.5.2 Percentage representation of WAWQI classification in Pre-monsoon & Post-monsoon season of year 2016

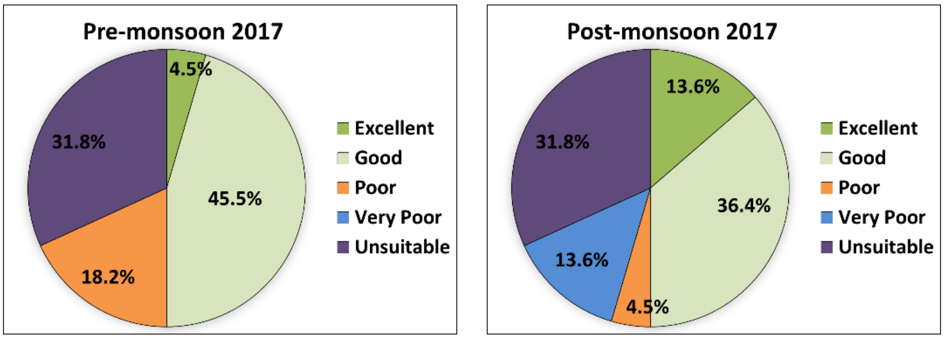


Fig. 5.5.3 Percentage representation of WAWQI classification in Pre-monsoon & Post-monsoon season of year 2017

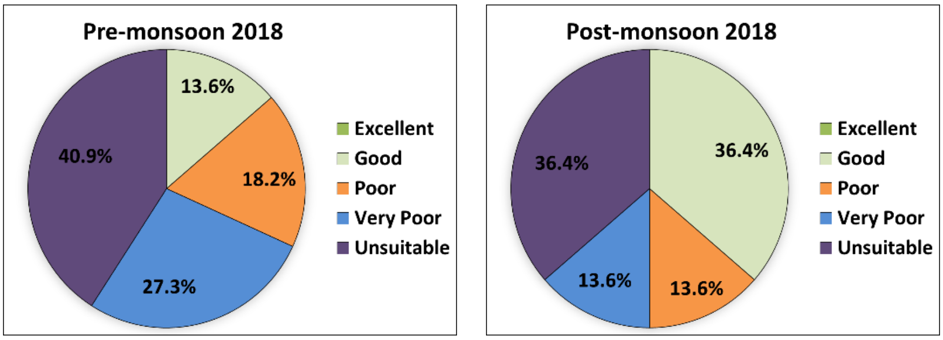


Fig. 5.5.4 Percentage representation of WAWQI classification in Pre-monsoon & Post-monsoon season of year 2018

5.5.3 GROUNDWATER QUALITY INDEX (GWQI)

This method of calculating water quality index is simple and fairly accurate. The methodology of GWQI was first given by Ribeiro et al., (2002). Based on GWQI, groundwater in parts of Tumkur taluk in Karnataka was found unfit for drinking purpose. Around 99% of samples have water quality index value above 100 (Ramakrishnaiah et al., 2009). Quality of groundwater samples in Qazvin province, west central of Iran was determined by Saeedi, (2010) by the GWQI method and it was concluded that in many parts of Qazvin plateau, groundwater quality was very good & close to mineral water quality. In current study, GWQI was calculated in five steps-

Step 1 – Thirteen water quality parameters (pH, TDS, turbidity, TH, TA, Ca^{2+}, Mg^{2+}, B, Cl^-, F^-, SO_4^{2-}, NO_3^- and NH_3) were selected to calculate GWQI. A weightage (w_i) of 1 to 5 was given to each parameter according to its comparative contribution in water quality (Mandal & Kumar, 2012; Sadat-Noori et al., 2014; Kumar et al., 2015). The highest weightage of 5 has been given to parameters such as TDS, boron, chloride, fluoride, sulphate and nitrate as these are major contributor in water quality assessment. pH, turbidity and ammonia has assigned a weight of 4. A weightage of 3 has been given to calcium and magnesium due to relatively lesser health hazard. Total hardness and total alkalinity is given the weight of 2. All the parameters were assigned a weightage between 1 and 5 according to participation in water quality assessment.

Step 2 – The relative weight (W_i) for each parameter was calculated by the expression- $W_i = \frac{\text{wi}}{\sum_{i=1}^{n} \text{wi}}$ (5)

The calculated values of Relative weight (W_i) are given in Table – 5.5.2.

Step 3 – Quality rating scale (Q_i) for individual parameter is the percentage of actual value to the standard value of that parameter.

$Q_i = (C_i/S_i) \times 100$ (6)

Where C_i = Actual value of physico-chemical parameter in the analysed water sample (mg/L), and

S_i = Standard value for each physico-chemical parameter (mg/L) (BIS 10500, 2012).

Step 4 – Sub-index (SI_i) for each parameter = $W_i \times Q_i$ (7)

Step 5 – Overall Groundwater quality index (GWQI) was computed by aggregating all the sub-indices for each parameter.

$$GWQI = \Sigma SI_i \quad (8)$$

The calculated GWQI values of collected groundwater samples during study period are given in Table – 5.5.3.

Table – 5.5.2 - Relative weight (W_i) of Physico-chemical parameters

Parameters	Standard value (BIS 10500, 2012)	Weight (w_i)	Relative weight (W_i)
pH	6.5-8.5	4	0.076923
TDS	500	5	0.096154
Turbidity	1	4	0.076923
TH	200	2	0.038462
TA	200	2	0.038462
Ca	75	3	0.057692
Mg	30	3	0.057692
B	0.5	5	0.096154
Cl	250	5	0.096154
F	1	5	0.096154
SO_4	200	5	0.096154
NO_3	45	5	0.096154
NH_3	0.5	4	0.076923
		$\sum w_i=52$	$\Sigma W_{i\,=}1$

GWQI value of analysed groundwater samples ranged from 86 (in post-monsoon sample of year 2017 at Dujana station & pre-monsoon sample of year 2017 at Sadopur station) to 557 (in pre-monsoon sample of year 2016 at Bisrakh Road station). During 2016 the variation in GWQI value in the groundwater was from 107 to 557 while, in 2017 it ranged from a minimum of 86 to a maximum of 469. It was observed that values ranged from 104 to 543 during year 2018. In year 2016 it was found maximum at Bisrakh Road water quality station and minimum at Duryai water quality station.

Table – 5.5.3 Ground water quality index (GWQI) of Groundwater Samples during study period

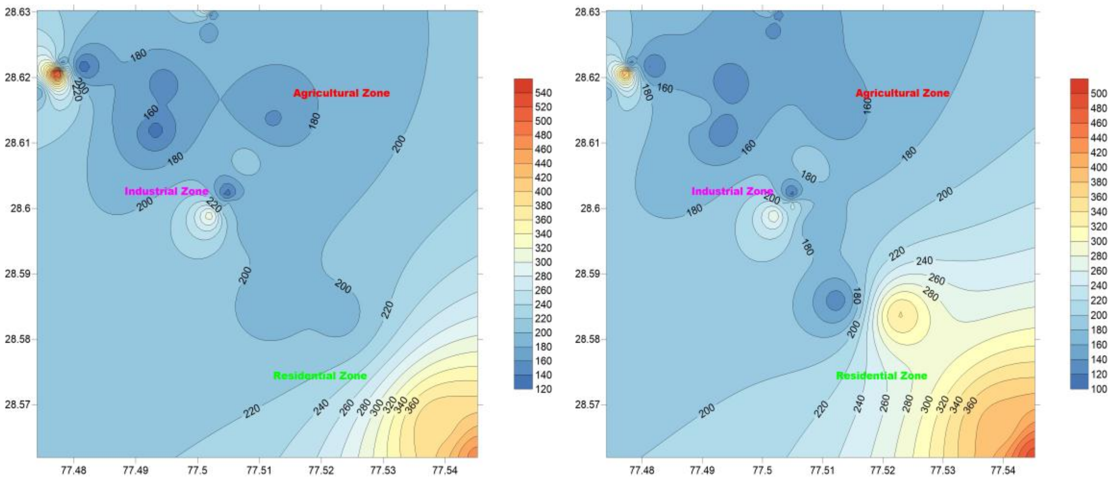
Sample No.	Water Quality Station	GWQI					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
S1	Duryai	319	214	256	250	262	193
S2	Duryai	123	107	116	116	149	119
S3	Duryai	168	134	138	121	164	132
S4	Talabpur	148	121	111	108	171	141
S5	Bisrakh Road	129	119	102	126	104	132
S6	Bisrakh Road	185	171	177	183	207	197
S7	Bisrakh Road	557	416	417	335	459	322
S8	Bisrakh Road	159	124	124	115	146	126
S9	Bisrakh Road	134	126	132	108	148	129
S10	Khera Dharampura	167	169	175	155	206	154
S11	Bishnuli	133	121	130	118	149	124
S12	Achheja	310	273	170	198	245	231
S13	Achheja	203	228	155	198	210	242
S14	Dujana	129	112	119	86	189	137
S15	Dujana	213	194	145	142	189	158
S16	Dujana	168	155	153	152	202	171
S17	Dujana	154	142	137	131	144	130
S18	Badalpur	188	160	161	153	190	167
S19	Sadopur	187	132	86	105	215	158
S20	Dairy Maccha	193	341	174	227	413	205
S21	Dhoom Manikpur	396	386	440	397	543	506
S22	Badhpura	468	488	469	431	366	293

In year 2017, the minimum GWQI value was observed at Dujana & Sadopur station and maximum at Badhpura station. In 2018 it was found maximum at Dhoom Manikpur and minimum at Bisrakh Road station. Analytical results showed that majority of samples (68.2%) have GWQI value between 100 & 200 (poor water quality), 14.40% of samples have GWQI value between 200 & 300 (very poor water quality), and 16% of samples GWQI value greater than 300 (unsuitable for drinking). None of the samples have excellent type of water. All the samples collected from Bisrakh Road (S7), Dhoom Manikpur (S21) and Badhpura (S22 except in post-monsoon season of year 2018) water quality station has GWQI value greater than 300. High value of GWQI in samples collected from industrial and residential zone was due to high ionic concentration.

Spatial distribution maps of GWQI value indicate the improvement in water quality in post-monsoon season (Fig. 5.5.5).

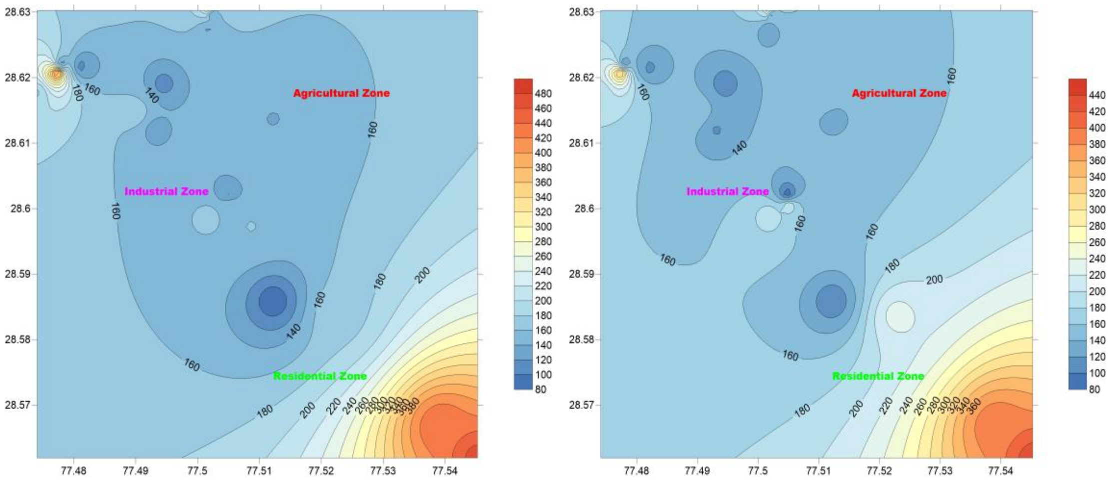
Percentage classification of groundwater samples in pre and post-monsoon season of year 2016 revealed that percent share of poor quality of water remained same in both season but percent share of samples with unsuitable quality of water decreased from 22.7% to 18.2% (Fig. 5.5.6). In year 2017, seasonal variation in drinking quality of water was not significant (Fig. 5.5.7). In year 2018, percentage of groundwater samples having poor quality of water increased from 50% to 72.7% in post-monsoon season however percent of very poor and unsuitable category of samples decreased in post-monsoon season (Fig. 5.5.8).

Babiker et al., (2007) proposed a GIS-based groundwater quality index (GQI) for Nasuno basin, Tochigi Prefecture, Japan by using WHO (World Health Organization) standards. They used 7 parameters (Cl^-, Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^- and TDS) to calculate GQI. The GQI values indicate that the groundwater quality in the study area was generally high (GQI > 90). Vasanthavigar et al., (2010) calculated WQI of 148 groundwater samples of Thirumanimuttar sub-basin of Tamilnadu by using BIS (Bureau of Indian Standards) standards to assess overall water quality for drinking purpose. The pre-monsoon groundwater samples showed poor water quality in comparison to post-monsoon samples.



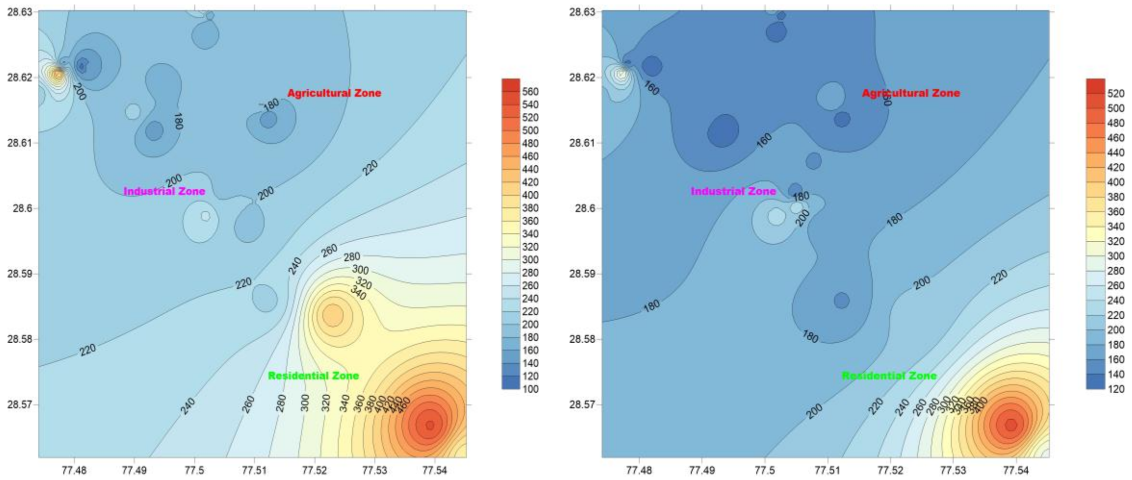
2016 (Pre-monsoon)

2016 (Post-monsoon)



2017 (Pre-monsoon)

2017 (Post-monsoon)



2018 (Pre-monsoon)

2018 (Post-monsoon)

Fig. 5.5.5 Spatial Distribution of GWQI in Groundwater Samples of study area during study period (2016-2018)

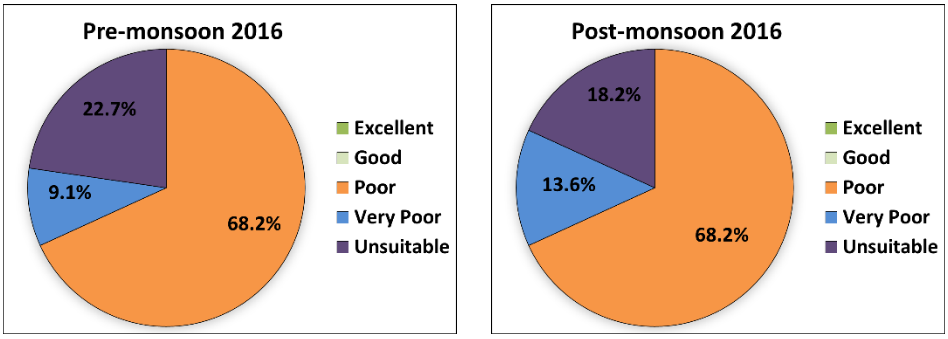


Fig. 5.5.6 Percentage representation of GWQI classification in Pre-monsoon & Post-monsoon season of year 2016

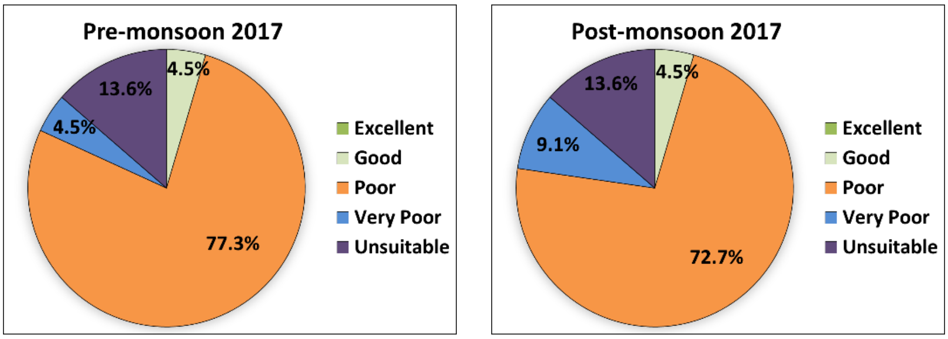


Fig. 5.5.7 Percentage representation of GWQI classification in Pre-monsoon & Post-monsoon season of year 2017

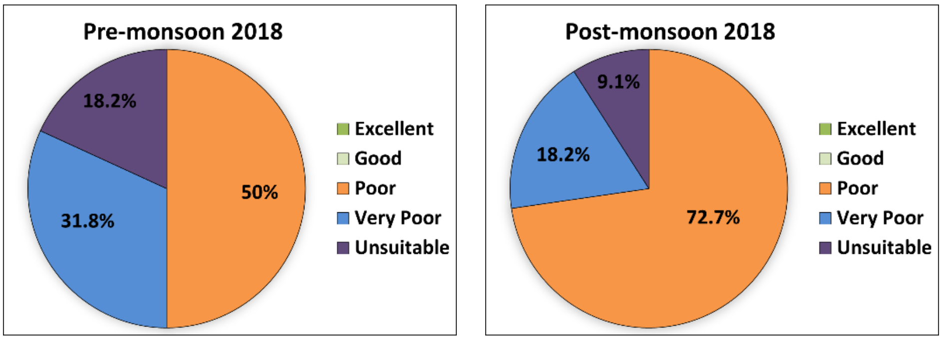


Fig. 5.5.8 Percentage representation of GWQI classification in Pre-monsoon & Post-monsoon season of year 2018

5.5.4 CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT WATER QUALITY INDEX (CCME WQI)

Canadian Council of Ministers of the Environment water quality index (CCME WQI) is based on upon the specific use of water: drinking, recreation, irrigation, livestock watering, wildlife and aquatic life (Husain et al., 1999). The mathematical expression for calculating CCME WQI was given by British Columbia Ministry of Environment, Lands and Parks. It was later revised by Alberta Environment taking into consideration three elements: scope, frequency & amplitude. A rating scale of 0 to 100 is given to the index value which represents worst to best quality of water (Table – 4.9). This rating scale is divided into five categories (CCME 2001; Sharma & Kansal 2011). First three factors scope (F_1), frequency (F_2) and amplitude (F_3) was calculated to compute CCME WQI.

1. Scope (F_1) was calculated by dividing the number of variables which do not attain quality objectives by the total number of measured variables & then multipling the result by 100.

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right) \times 100 \qquad (9)$$

2. Frequency (F_2) is the percentage of failed tests to the total number of tests.

$$F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \times 100 \qquad (10)$$

3. Amplitude (F_3) is the quantity by which failed tests do not attain their quality objectives. Three steps were used to calculate F_3.

(i) Excursion was calculated for two cases: when actual test value was greater than objective & actual test value was lesser than the objective.

$$excursion_i = \left(\frac{Failed\ test\ value_i}{Objective_j}\right) - 1 \text{ (when test value> objective)} \qquad (11)$$

$$excursion_i = \left(\frac{Objective_j}{Failed\ test\ values_i}\right) - 1 \text{ (when test value< objective)} \qquad (12)$$

(ii) The normalized sum of excursions (nse) was calculated by dividing the sum of all excursion by the total number of tests:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{number\ of\ tests} \qquad (13)$$

(iii) Amplitude (F_3) was derived by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a result ranging between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse+0.01}\right) \qquad (14)$$

CCME water quality index was calculated by using F_1, F_2, and F_3 from the above equations.

$$\text{CCMEWQI} = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \qquad (15)$$

The number 1.732 was used in the equation to regulate the resulting value between the rating scales 1 to 100. Calculated value of CCMEWQI of analysed groundwater samples are given in Table – 5.5.4.

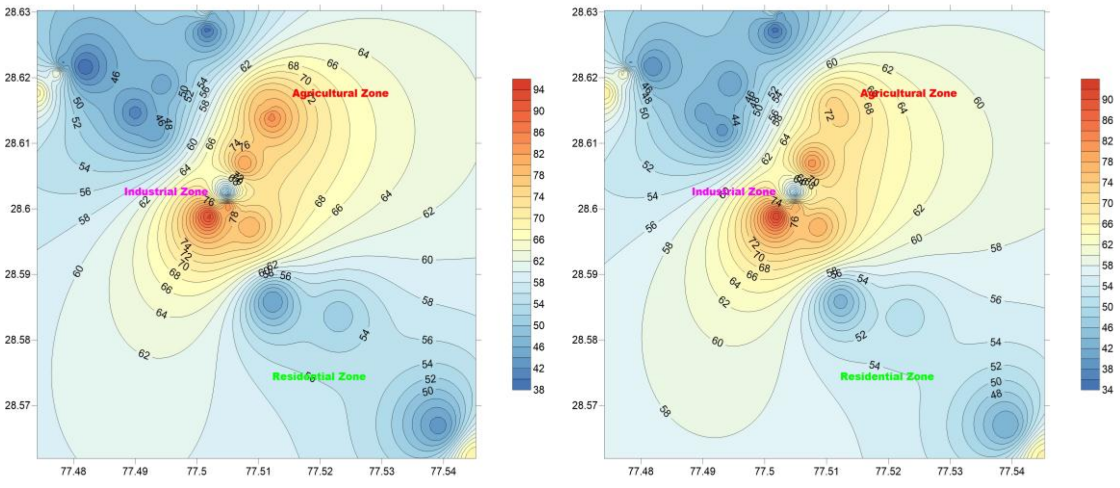
During study period (2016-2018), CCME WQI value of groundwater of study area ranged from 29 to 93. By comparing the obtained results with standards given by CCME, it was observed that groundwater quality in study area was poor, marginal, fair and good type (Table – 4.9). None of the sample has excellent type of water. During year 2016, CCME WQI value of groundwater samples ranged from 35 to 93, in year 2017, it ranged from 29 to 93 and in year 2018, it ranged from 33 to 93. According to the classification given by CCME WQI, 43.2% of samples have poor quality of water, 16.7% have marginal quality of water, 26.6% have fair quality of water and 13.6% have good quality of water. Sample collected from Duryai, Talabpur, Bisrakh Road, Khera Dharampura, Bishnuli, Sadopur and Dhoom Manikpur stations has poor quality of water (CCME WQI value; 0 – 44).

Spatial distribution of CCME WQI of analysed samples is given in Fig. 5.5.9. From the maps it was concluded that most of the sites have poor quality of water. Seasonal variation in quality of groundwater is presented in Fig. 5.5.10, 5.5.11 & 5.5.12. Percentage representation of CCME WQI classification in pre and post monsoon season of year 2016, 2017 and 2018 indicate that there was always increase in percentage of fair quality of samples in post-monsoon season (from 22.7 to 31.8%, from 22.7 to 31.8% and from 13.6 to 36.4% in 2016, 2017, 2018 respectively).

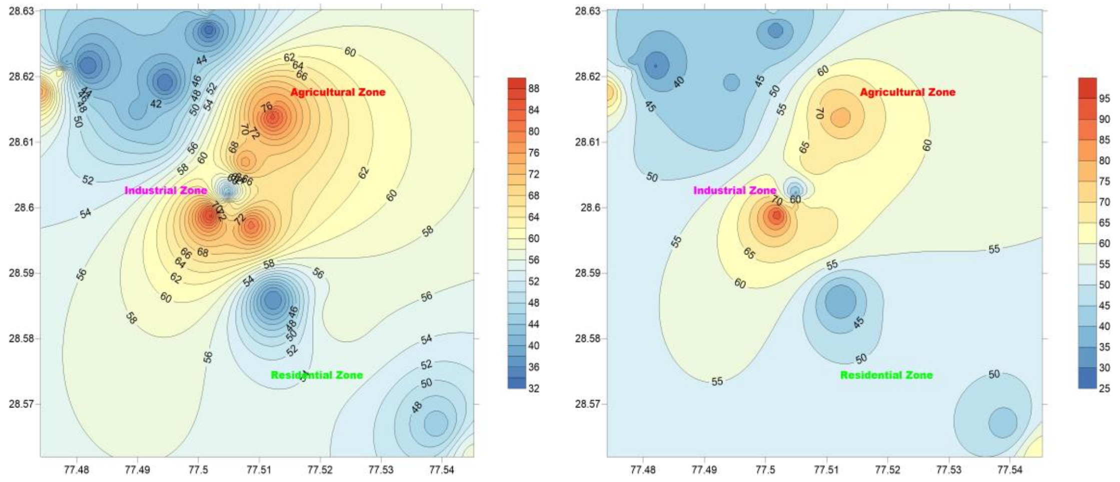
Magesh et al., (2013) assessed the groundwater quality of Dindigul district of Tamil Nadu and reported that majority of the analysed samples fall into good to marginal type of category of water.

Table – 5.5.4 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) of Groundwater Samples during study period

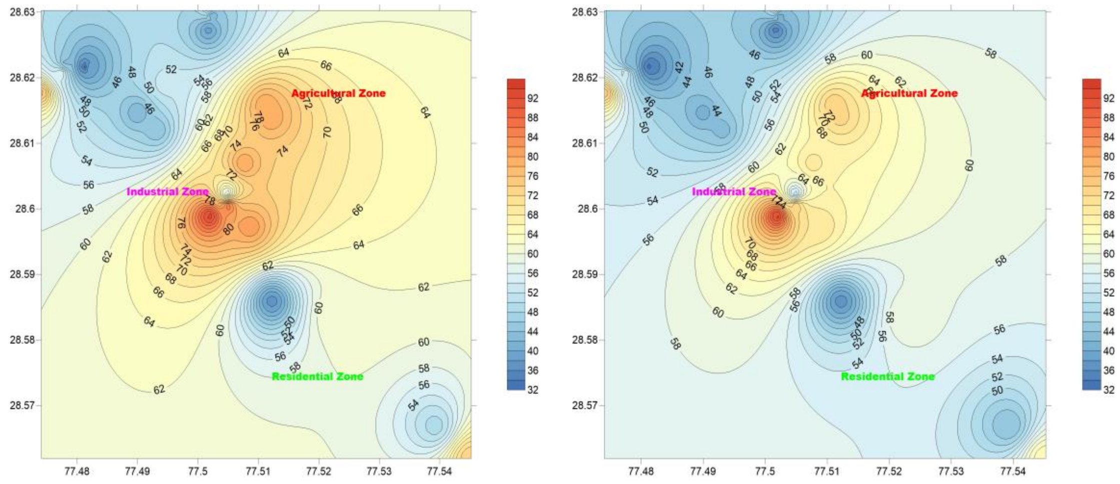
Sample No.	Water Quality Station	CCME WQI					
		2016		2017		2018	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
S1	Duryai	61	54	52	51	55	53
S2	Duryai	44	38	40	39	40	39
S3	Duryai	39	35	32	31	39	35
S4	Talabpur	45	40	34	39	53	47
S5	Bisrakh Road	39	38	34	33	33	33
S6	Bisrakh Road	69	68	75	75	77	76
S7	Bisrakh Road	65	64	63	56	56	55
S8	Bisrakh Road	43	43	39	38	43	42
S9	Bisrakh Road	38	38	34	29	40	35
S10	Khera Dharampura	41	41	41	40	42	41
S11	Bishnuli	44	39	44	40	44	43
S12	Achheja	93	92	87	93	93	93
S13	Achheja	85	79	67	72	86	74
S14	Dujana	47	46	43	38	57	52
S15	Dujana	82	81	75	69	80	69
S16	Dujana	78	73	74	72	80	74
S17	Dujana	85	73	85	79	80	73
S18	Badalpur	80	78	81	69	82	70
S19	Sadopur	44	43	36	35	37	37
S20	Dairy Maccha	51	51	57	51	62	60
S21	Dhoom Manikpur	43	42	45	43	49	44
S22	Badhpura	70	67	57	65	74	66



2016 (Pre-monsoon) 2016 (Post-monsoon)



2017 (Pre-monsoon) 2017 (Post-monsoon)



2018 (Pre-monsoon) 2018 (Post-monsoon)

Fig. 5.5.9 Spatial Distribution of CCME WQI in Groundwater Samples of study area during study period (2016-2018)

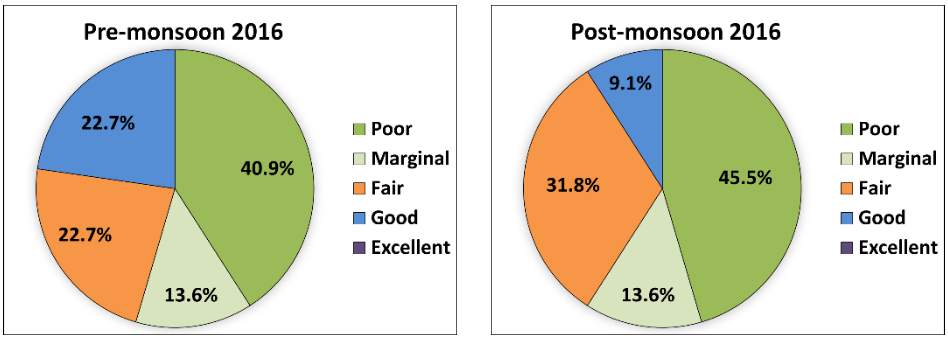


Fig. 5.5.10 Percentage representation of CCME WQI classification in Pre-monsoon & Post-monsoon season of year 2016

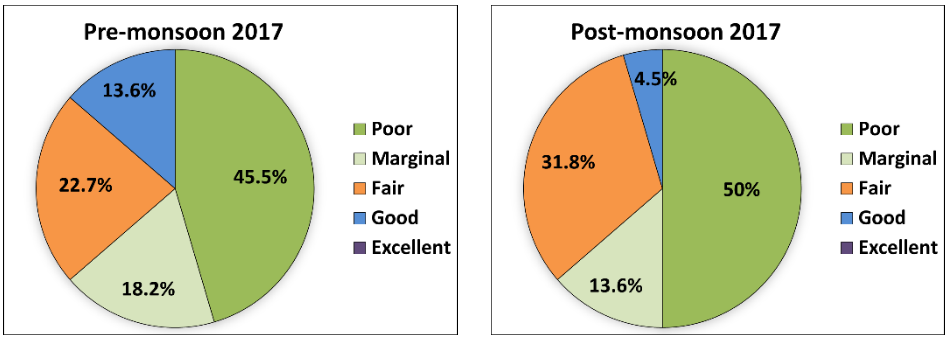


Fig. 5.5.11 Percentage representation of CCME WQI classification in Pre-monsoon & Post-monsoon season of year 2017

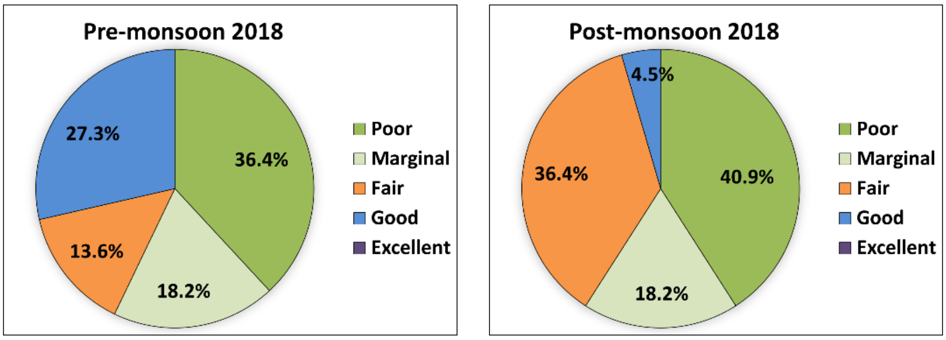


Fig. 5.5.12 Percentage representation of CCME WQI classification in Pre-monsoon & Post-monsoon season of year 2018

SUMMARY

Increasing population, industrialization and urbanization generates a lot of solid wastes and liquid wastes. Disposal of this waste material in indiscriminate manner leads to severe damage to environment. To know the quality of groundwater of study area, water quality indices were calculated for all collected groundwater samples. A slight increase in water quality indices was recorded during the study period. The results of water quality index showed that drinking water quality of 37.9% (WAWQI), 16% (GWQI) and 43.20% (CCME WQI) of groundwater samples, was not suitable. A variation was observed in quality of groundwater in different zone of study area. On the basis of WQI, quality of groundwater at Duryai water quality station in agricultural zone, Bisrakh Road water quality station in industrial zone and Sadopur, Dhoom Manikpur, Dairy Maccha & Badhpura water quality stations in residential zone was not safe for direct consumption.

Spatial distribution of water quality indices revealed that groundwater of village Duryai, Bisrakh Road, Achheja, Dujana, Sadopur, Dhoom Manikpur, Dairy Maccha, and Badhpura of district Gautam Budh Nagar of India, was not fit for human consumption.

At most of the water quality station, improvement in groundwater quality was observed in post-monsoon samples due to recharging of ground aquifers. At few stations (Duryai, Bisrakh Road, Khera Dharampura, Achheja, Sadopur, Dairy Maccha and Badhpura) further deterioration in groundwater quality was observed in post-monsoon season. It indicated much stress on ground aquifers and less groundwater recharge in that areas. Groundwater of almost all the sampling sites was contaminated and not good for drinking. Proper management for the disposal of domestic and industrial wastes is required to improve the quality of water.

REFERENCES

1. Abah J, Ubwa S.T., Onyejefu D.I., Nomor S.A., 2013. Assessment of some trace metals content of oreochromis niloticus obtained from river Okpokwu, Apa Benue State, Nigeria. Research Journal of Chemical Sciences. 3, (3) 70–75.
2. Abbasi S.A., 2002. Water Quality Indices, State of the Art Report. Scientific Contribution No. INCOH/SAR–25/2002. INCOH. National Institute of Hydrology, Roorkee.
3. Abbasi T., Abbasi S.A., 2012. Water Quality Indices. Elsevier. The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK.
4. Abdalla F., Khalil R., 2018. Potential effects of groundwater and surface water contamination in an urban area, Qus City, Upper Egypt. Journal of African Earth Sciences. 141, 164-178.
5. Aboyeji O.S., Eigbokhan S.F., 2016. Evaluations of groundwater contamination by leachates around Olusosun open dumpsite in Lagos metropolis, southwest Nigeria. Journal of Environmental Management. 183, (1) 333-341.
6. Ackah M., Agyemang O., Anim A.K., Osei J., Bentil N.O., Kpattah L., Gyamfi E.T., Hanson J.E.K., 2011. Assessment of groundwater quality for drinking and irrigation: the case study of Teiman-Oyarifa Community, Ga East Municipality, Ghana. Proceedings of the International Academy of Ecology and Environmental Sciences. 1, (4) 186194.
7. Adelekan B.A., Abegunde K.D., 2011. Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. International Journal of the Physical Sciences. 6, (5) 1045-1058.
8. Adhikary R., Mandal V., 2017. Status of Arsenic Toxicity in Ground Water in West Bengal, India: A Review, MOJ Toxicology. 3, (5) 104-108. DOI: 10.15406/mojt.2017.03.00063.
9. Adimalla N., Venkatayogi S., 2018. Geochemical characterization and evaluation of groundwater suitability for domestic and agricultural utility in semi-arid region of Basara, Telangana State, South India. Applied Water Science. 8, 44.
10. Adriano D.C., 1986. Trace Elements in the Terrestrial Environment. Springer-Verlag. New York.

11. Aghazadeh N., Mogaddam A.A., 2010. Assessment of Groundwater Quality and its Suitability for Drinking and Agricultural Uses in the Oshnavieh Area, Northwest of Iran. Journal of Environmental Protection. 1, 30-40.
12. Agrawal V.P., Sastry K.V., Gupta P.K., 1978. Lead induced histopathological alteration in digestive system of Channa punctatus, Abstract of IV All India Congress of Zoology, Sponsored by the Zoological Society of India, Bodha-Gaya.
13. Ahada C.P.S., Suthar S., 2018. Assessing groundwater hydrochemistry of Malwa Punjab, India, Arabian Journal of Geosciences. 11, 17.
14. Ahamed A.J., Loganathan K., Ananthakrishnan S., Ahmed J.K.C., Ashraf M.A., 2017. Evaluation of Graphical and Multivariate statistical methods for classification and Evaluation of Groundwater in Alathur block, Perambalur district, India. Applied Ecology and Environmental Research. 15, (3) 105-116.
15. Akakuru O.C., Akudinobi B.E.B., 2018. Determination of Water Quality Index and Irrigation Suitability of Groundwater Sources in parts of Coastal Aquifers Eastern Niger delta, Nigeria. International Journal of Applied and Natural Sciences 7, (1) 1-6.
16. Allhajjar B.J., Gordon C., Harkin J.M., 1990. Indicators of chemical pollution from septic system. Ground Water. 28 (4).
17. Al-Obaidi M., 2017. Evaluation of Groundwater Quality in East of ThiQar Governorate (South Iraq), Iraqi Journal of Science. 58, (4C) 2383-2391.
18. Anake W.U., Benson N.U., Akinsiku A.A., Ehi-Eromosele C.O., Adeniyi I.O., 2014. Assessment of trace metals in drinking water and groundwater sources in Ota, Nigeria. International Journal of Scientific and Research Publications. 4, (5) 1-4.
19. APHA, 2012. Standard Methods for the Examination of Water and Wastewater, 22nd Ed., American Public Association, American Water Works Association, Water Environment Federation, Edited by Eugene W. Rice, Rodger B. Baird, Andrew D. Eaton, Lenore S. Clesceri.
20. Arslan H., 2017. Determination of temporal and spatial variability of groundwater irrigation quality using geostatistical techniques on the coastal aquifer of Çarşamba Plain, Turkey, from 1990 to 2012. Environmental Earth Sciences 76, 38.
21. Ayedun H., Oyede R.T., Osinfade B.G., Oguntade B.K., Umar B.F., Abiaziem C.V., 2012. Groundwater quality around new cement factory, Ibese, Ogun State,

Southwest Nigeria. African Journal of Pure and Applied Chemistry. 6, (13) 219-223.

22. Azom M.R., Mahmud K., Yahya S.M., Sontu A., Himon S.B., 2012. Environmental Impact Assessment of Tanneries: A Case Study of Hazaribag in Bangladesh. International Journal of Environmental Science and Development. 3, (2) 152-156.
23. Babiker I.S., Mohamed M.A.A., Hiyama T., 2007. Assessing groundwater quality using GIS. Water Resources Management. 21, (4) 699–715.
24. Balan I.N., Shivakumar M., Kumar P.D.M., 2012. An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India. Chronicles Young Scientists. 3, (2), 146–150.
25. Barakat M.A., 2011. New trends in removing heavy metals from industrial wastewater. Arabian Journal of Chemistry. 4, (4) 361-377.
26. Bauder T.A., Waskom R.M., Davis J.G., 2007. Irrigation Water Quality Criteria, No. 0.506, Colorado State University, U.S. Department of Agriculture.
27. Bech A.V., 1966. The technology of magnesium and its alloys, In: McGraw Hill encyclopaedia of science and technology, New York, McGraw Hill.
28. Belay A.A., 2010. Impacts of Chromium from Tannery Effluent and Evaluation of Alternative Treatment Options. Journal of Environmental Protection. 1, (1) 53-58.
29. Belkhiri L., Mouni L., Narany T.S., Tiri A., 2017. Evaluation of potential health risk of heavy metals in groundwater using the integration of indicator kriging and multivariate statistical methods. Groundwater for Sustainable Development. 4, 12-22.
30. Bhardwaj V., Kumar P., Singhal G., 2014. Toxicity of Heavy Metals Pollutants in Textile Mills Effluents. International Journal of Scientific & Engineering Research. 5, (7) 664-666.
31. Bhargava D.S., 1987. Nature and the Ganga. Environmental Conservation. 14, (4) 307–318.
32. Bhattacharya P., Hossain M., Rahman S.N., Robinson C., Nath B., Rahman M., Islam M.M., Brömssen M.V., Ahmed K.M., Jacks G., Chowdhury D., Rahman M., Jakariya M., Persson L.A., Vahter M., 2011. Temporal and seasonal variability of arsenic in drinking water wells in Matlab, southeastern Bangladesh: A preliminary evaluation on the basis of a 4 year study. Journal of Environmental Science and Health, Part A. 46, (11) 1177-1184.

33. Bhattacharyya P., Chakraborty A., Chakrabarti K., Tripathy S., Powell M.A., 2005. Chromium uptake by rice and accumulation in soil amended with municipal solid waste compost. Chemosphere. 60, 1481-1486.
34. Bhattacharyya R., Ojha S.N., Singh U.K., 2017. Risk Prediction Based On Heavy Metal Distribution in Groundwater. World Academy of Science, Engineering and Technology. International Journal of Environmental and Ecological Engineering. 11, (5).
35. Brindha K., Elango L., 2012. Impact of Tanning Industries on Groundwater Quality near a Metropolitan City in India. Water Resources Management. 26, (6) 1747–1761.
36. Brindha K., Elango L., Rajesh V.G., 2010. Occurrence of Chromium and Copper in Groundwater Around Tanneries in Chromepet Area of Tamil Nadu, Indian Journal of Environmental Protection. 30, (10) 818-822.
37. Brown R.M., Mccleiland N.J., Deiniger R.A., O'Connor M.F.A., 1972. Water quality index – crossing the physical barrier (Jenkis SH, ed^{n}) International Conference on Water Pollution Research, Jerusalem. 6, 787–797.
38. Brown R.M., McCLelland N.I., Deininger R.A., O'Connor M.F., 1972. A water quality index-crashing the psychological barrier. Indicators of Environmental Quality. 1, (1) 173–182.
39. Brown R.M., McClelland N.I., Deininger R.A., Tozer R.G., 1970. A water quality index: do we dare? Water Sewage Works. 117, (10), 339–343.
40. Bundela P.S., Sharma A., Pandey A.K., Pandey P., Awasthi A.K., 2012. Physicochemical Analysis of Ground Water Near Municipal Solid Waste Dumping Sites in Jabalpur, International Journal of Plant. Animal and Environmental Sciences. 2, (1) 217-222.
41. Bureau of Indian Standards, 2012. Indian standard specification for drinking water (IS:10500). Manak Bhawan, New Delhi, India.
42. Canadian Council of Ministers of the Environment, 2001. Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, User's Manual. In: Canadian environmental quality guidelines, 1999, Winnipeg, Canadian Council of Ministers of the Environment.
43. Cempel M., Nikel G., 2006. Nickel: A Review of Its Sources and Environmental Toxicology. Polish Journal of Environmental Study. 15, (3) 375-382.

44. Central Water Commission (CWC) 2014. Status of trace and toxic metals in Indian rivers. Ministry of Water Resources, New Delhi, pp 1–185.
45. Chabukdhara M., Gupta S.K., Kotecha Y., Nema A.K., 2017. Groundwater quality in Ghaziabad district, Uttar Pradesh, India: Multivariate and health risk assessment. Chemosphere. 179, 167-178.
46. Chapman D., 1996. Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition, UNESCO/WHO/UNEP ISBN 0 419 21590 5 (HB) 0 419 21600 6 (PB)
47. Chatopadhyay S.M., Arora H.C., Sharma V.P., 1973. Characteristics of feasibility of chrome tanning waste. Indian Journal of Environmental Health. 15, 208.
48. Chaturvedia A., Bhattacharjeea S., Singha A.K., Kumar V., 2018. A new approach for indexing groundwater heavy metal pollution. Ecological Indicators. 87, 323-331.
49. Cheremisinoff N.P., 1997. Chapter 7 - Treating Contaminated Groundwater and Leachate, Groundwater remediation and Treatment Technologies. 259-308.
50. Clarkson T.W., 1988. Biological Monitoring of Toxic Metals; Plenum Press: New York, pp. 265-282.
51. Cox C.R., 1964. Operation and Control of Water Treatment Processes. Geneva, World Health Organization.
52. Cude C.G., 2001. Oregon Water Quality Index: A tool for evaluating water quality management effectiveness. Journal of the American Water Resources Association. 37, (1) 125–137.
53. Ćurković M., Sipos L., Puntarić D., Dodig-Ćurković K., Pivac N., Kralik K., 2016. Arsenic, Copper, Molybdenum, and Selenium Exposure through Drinking Water in Rural Eastern Croatia. Polish Journal of Environmental Studies. 25, (3) 981-992.
54. Dar M.A., Sankar K., Dar I.A., 2011. Major ion chemistry and hydrochemical studies of groundwater of parts of Palar river basin, Tamil Nadu, India, Environmental Monitoring and Assessment. 176, (1-4) 621-636.
55. Daw M.M., Ali E.R., Toriman M.E., 2018. Nitrate contamination in groundwater agricultural of Samno and Elzegan area, Fazan region, Libya. International Journal of Engineering & Technology. 7, (2.29) 56–59.
56. Deshpande S.M., Aher K.R., 2012. Evaluation of Groundwater Quality and its Suitability for Drinking and Agriculture use in Parts of Vaijapur, District Aurangabad, MS, India. Research Journal of Chemical Sciences. 2, (1) 25-31.

57. Devi S., Kumar R.P., 2012. Physico-chemical analysis of ground water sample near Industrial area, Cuddalore district, Tamilnadu, India. International Journal of ChemTech Research. 4, (1) 29-34.
58. Dinius S.H., 1987. Design of an index of water quality. Journal of the American Water Resources Association, Water Resources Bulletin. 23, (5) 833–843.
59. Doneen L.D., 1964. Notes on water quality in agriculture. Davis: Water Science and Engineering, University of California.
60. Ducci D., 2018. An easy-to-use method for assessing nitrate contamination susceptibility in groundwater. Geofluids. https:// doi.org/10.1155/2018/1371825
61. Dural M., Goksu L.M., Ozak A.A., 2007. Investigation of heavy metal levels in economically important fish species captured from the Tuzla lagoon. Food Chemistry. 102, 415- 421.
62. Dutta A., Gupta S., Mondal N.K., 2015. Agricultural Application of Rice Mill wastes as a substitution of Potash Fertilizer in Potato (Solanum tuberosum) cultivation. Global Journal of Engineering Science and Research Management. 2, (12) 87-98.
63. Eaton F.M., 1950. Significance of Carbonates in Irrigation Waters. Soil Science, 69, 123-134.
64. Elisante E., Muzuka A.N.N., 2017. Occurrence of nitrate in Tanzanian groundwater aquifers: a review. Applied Water Science. 7, (1) 71–87.
65. Ensink J.H.J., Simmons R.W., Van der Hoek W., 2007. Wastewater Use in Pakistan: The Cases of Haroonabad and Faisalabad. The International Development Research Centre, Canada. http:// www.idrc.ca/fr/ev-68336-201-1-DO_TOPIC.html.
66. Ezekwe I.C., Odu N.N., Chima G.N., Opigo A., 2012. Assessing regional groundwater quality and its health implications in the Lokpaukwu, Lekwesi and Ishiagu mining areas of southeastern Nigeria using factor analysis. Environmental Earth Sciences. 67, 971–986.
67. Fadiran A.O., Dlamini S.C., Mavuso A.A., 2008. Comparative study of the phosphate levels in some surface and ground water bodies of Swaziland. Bulletin of Chemical Society of Ethiopia. 22, (2) 197-206.
68. Faisal K., Tahir H., Ashok L., 2003. Water quality evaluation and trend analysis in selected watersheds of the Atlantic region of Canada. Environmental Monitoring and Assessment. 88, (1–3) 221–248.

69. Farshad A.A., Imandel K. 2003. An assessment of groundwater nitrate and nitrite levels in the industrial sites in the west of Tehran. Journal of School of Public Health and Institute of Health Research. 1, (2).
70. Faust S.D., Winka A., Belton T., Tucker R., 1983. Assessment of the chemical and biological significance of arsenical compounds in a heavily contaminated watershed part II. Analysis and distribution of several arsenical species. Journal of Environmental Science and Health A. 18, (3) 389–411.
71. Fipps G., 2003. Irrigation water quality standards and salinity management strategies. Texas Agricultural Extension Service, Texas A&M University System, College Station, TX (USA). B-1667, 4-03, pp 1–19.
72. Gaikwad S., Gaikwad S., Meshram D., Wagh V., Kandekar A., Kadam A., 2019. Geochemical mobility of ions in groundwater from the tropical western coast of Maharashtra, India: implication to groundwater quality. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-019-00312-9.
73. General standards for discharge of environmental pollutants, Part- A, Effluents, Schedule-VI, The Environment (Protection) Rules, 1986.
74. Goyal S.K., Chaudhary B.S., Singh O., Sethi G.K., Thakur P.K., 2010. GIS based spatial distribution mapping and suitability evaluation of groundwater quality for domestic and agricultural purpose in Kaithal district, Haryana state, India. Environmental Earth Sciences. 61, 1587–1597.
75. Gupta R., Mishra A.K., 2016. Groundwater quality analysis of quaternary aquifers in Jhajjar district, Haryana, India: Focus on groundwater fluoride and health implications. Alexandria Engineering Journal. 57, (1) 375–381.
76. Han Z., Ma H., Shi G., He L., Wei L., Shi Q., 2016. A review of groundwater contamination near municipal solid waste landfill sites in China. Science of the Total Environment. 569-570, 1255-1264.
77. Hanna-Attisha M., LaChance J., Sadler R.C., Schnepp A.C., 2016. Elevated Blood Lead Levels in Children Associated With the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response. American Journal of Public Health, 106, (2) 283-290.
78. Haritash A.K., Kaushik C.P., Kaushik A., Kansal A., Yadav A.K., 2008. Suitability assessment of groundwater for drinking, irrigation and industrial use in some North Indian villages. Environmental Monitoring and Assessment. 145, 397–406.

79. Harper L.A., Catchpole V.R., Davis R., Weier K.L., 1983. Ammonia volatilization: Soil, plant, and microclimate effects on diurnal and seasonal fluctuations. Agronomy Journal. 75, (2) 212-218.
80. Harrison R.M., Laxen D.P.H., 1984. Lead in atmosphere, In Lead pollution-causes and control, Chapman and Hall Ltd. London; 10.
81. Harrison T.D., Cooper J.A.G., Ramm A.E.L., 2000. Water quality and aesthetics of South African estuaries. Department of Environmental Affairs and Tourism. Unpublished CSIR report to the Department of Environmental Affairs & Tourism ENV-DC-2000-001, South Africa.
82. Harshan S., Thushyanthy M., Gunatilake J., Srivaratharasan T., Gunaalan K., 2017. Assessment of water quality index of groundwater quality in Chunnakam and Jaffna Town, Sri Lanka. Vingnanam Journal of Science. 13, (1–2) 84–91.
83. Hasalam S.M., 1991. River Pollution – An ecological Perspective. Belhaven Press: Great Britain.
84. Health Canada (2013). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Nitrate and Nitrite. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. (Catalogue No H144-13/2-2013EPDF).
85. Hong Y., Ye B., Kim Y., Kim B., Kang G., Kim J., Song K., Kim Y., Seo J., 2017. Investigation of Health Effects According to the Exposure of Low Concentration Arsenic Contaminated Ground Water. International Journal of Environmental Research and Public Health. 14, (12) 1461.
86. Horton R.K., 1965. An index number system for rating water quality. Journal of the Water Pollution Control Federation. 37, (3) 300–306.
87. Hurley T., Sadiq R., Mazumder A., 2012. Adaptation and evaluation of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for use as an effective tool to characterize drinking source water quality. Water Resources. 46, (11) 3544–3552.
88. Husain T., Khan A.A., Mukhtasor A., 1999. Final Report on Water Quality Index for Northwest Territories. Water Management Planning Section, Yellowknife. 12–13.
89. Ibraheem A.M., Mazhar Nazeeb Khan S.M., 2017. Assessment of Heavy Metal Concentration of Groundwater in Veppanthattai Block, Perambalur District, Tamil Nadu. World News of Natural Sciences. 12, 21-26.

90. Ibraheem M., Khan M.N., Kumar R.A., 2015. Seasonal variation of groundwater quality in Veppanthattai block of Perambalur district, Tamilnadu-implements of the water quality index method. Journal of Chemical and Pharmaceutical Research. 7, (5) 938-943.
91. Idrees N., Tabassum B., Allah E.F.A., Hashem A., Sarah R., Hashim M., 2018. Groundwater contamination with cadmium concentrations in some West U.P. Regions, India. Saudi Journal of Biological Sciences. 25, 1365–1368.
92. Institute of Environmental Conservation and Research INECAR (2000) Position paper against mining in Rapu-Rapu. INECAR, Ateneo de Naga University, Philippines.
93. Ishaku J.M., Ahmed A.S., Abubakar M.A., 2011. Assessment of groundwater quality using chemical indices and GIS mapping in Jada area, Northeastern Nigeria. Journal of Earth Sciences and Geotechnical Engineering. 1, (1) 35-60.
94. Islam M.A., Zahid A., Rahman M.M., Rahman M.S., Islam M.J., Akter Y., Shammi M., Bodrud-Doza M., Roy B., 2016. Investigation of Groundwater Quality and Its Suitability for Drinking and Agricultural Use in the South Central Part of the Coastal Region in Bangladesh. Water Quality Exposure and Health. DOI 10.1007/s12403-016-0220-z
95. Jampani M., Huelsmann S., Liedl R., Sonkamble S., Ahmed S., Amerasinghe P., 2018. Spatio-temporal distribution and chemical characterization of groundwater quality of a wastewater irrigated system: A case study. Science of the Total Environment. 636, 1089-1098.
96. Janardhana Raju N., 2007. Hydrogeochemical parameters for assessment of groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Pradesh, South India. Environmental Geology. 52, 1067–1074.
97. Jayasumana C., Fonseka S., Fernando A., Jayalath K., Amarasinghe M., Siribaddana S., Gunatilake s., Paranagama P., 2015. Phosphate fertilizer is a main source of arsenic in areas affected with chronic kidney disease of unknown etiology in Sri Lanka, SpringerPlus. 4, 90.
98. Jung M.C., 2001. Heavy metal contamination of soils and waters in and around the Imcheon Au–Ag mine, Korea. Applied Geochemistry. 16, 1369–1375.
99. Kaka E.A., Akiti T.T., Nartey V.K., Bam E.K.P., Adomako D., 2011. Hydrochemistry and evaluation of groundwater suitability for irrigation and

drinking purposes in the southeastern Volta river basin: manya krobo area, Ghana, Elixir Agriculture. 39, 4793-4807.

100. Kamble B.S., Saxena P.R., 2016. Environmental impact of municipal dumpsite leachate on groundwater quality in Jawaharnagar, Rangareddy, Telangana, India. Applied Water Science. DOI 10.1007/s13201-016-0480-6.

101. Kammoun S., Re V., Trabelsi R., Zouari K., Daniele S., 2018. Assessing seasonal variations and aquifer vulnerability in coastal aquifers of semi-arid regions using a multi-tracer isotopic approach: the case of Grombalia (Tunisia). Hydrogeology Journal. https://doi.org/10.1007/s10040-018-1816-0.

102. Kanagaraj G., Elango L., 2019. Chromium and fluoride contamination in groundwater around leather tanning industries in southern India: Implications from stable isotopic ratio δ^{53}Cr/ δ^{52}Cr, geochemical and geostatistical modelling. Chemosphere. 220, 943-953.

103. Kannan K., 1991. Fundamentals of Environmental Pollution, S. Chand and Company Ltd., New Delhi.

104. Kannel P.R., Lee S., Lee Y.S., Kanel S.R., Khan S.P., 2007. Application of Water Quality Indices and Dissolved Oxygen as Indicators for River Water Classification and Urban Impact Assessment, Environmental Monitoring and Assessment. 132, (1-3) 93–110.

105. Karthika I.N., Jesu A., Dheenadayalan M.S., 2015. The Physico –Chemical Analysis of Paper Industry Effluent and its Impact of Ground Water Quality at Madathukulam, Udumalpet City, International Journal of Pharm Tech Research. 8, (6) 12-18.

106. Katariya H.C., 1994. An evaluation of water quality of Kaliasot river, Indian Journal of Environmental Protection.14, 690-694.

107. Keesari T., Ramakumar K.L., Chidambaram S., Pethperumal S., Thilagavathi R., 2016. Understanding the hydrochemical behavior of groundwater and its suitability for drinking and agricultural purposes in Pondicherry area, South India – A step towards sustainable development, Groundwater for Sustainable Development. 2-3, 143-153.

108. Kelly W.P., 1940. Permissible composition and concentration of irrigation waters. Proceedings of ASCE, 66, 607.

109. Kelly W.P., 1951. Alkali soils—their formation, properties and reclamation. New York: Reinhold.

110. Khanikar L., Gogoi R.R., Das N., Deka J.P., Das A., Kumar M., Sharma K.P., 2017. Groundwater appraisal of Dhekiajuli, Assam, India: an insight of agricultural suitability and arsenic enrichment. Environmental Earth Sciences. 76, 530.

111. Kinniburgh D.G., Smedley P.L., 2001. Arsenic contamination of groundwater in Bangladesh. Volume 1: Summary. BGS Technical Report WC/00/19, British Geological Survey & Department of Public Health Engineering, p. 15.

112. Kolawole O.M., Afolayan O., 2017. Assessment of Groundwater Quality in Ilorin, North Central Nigeria. Arid Zone Journal of Engineering, Technology and Environment. 13, (1) 111-126.

113. Kudesia V.P., Kudesia R, 1998. Water Pollution, A Pragati Publication, 1998 Edition.

114. Kumar A., Bharti, Malyan S.K., Kumar S.S., Dutt D., Kumar V., 2019. An assessment of trace element contamination in groundwater aquifers of Saharanpur, Western Uttar Pradesh, India. Biocatalysis and Agricultural Biotechnology. 20, 101213.

115. Kumar A., Kumar V., Dhiman N., Ojha A., Bisen P., Singh A., Markandeya, 2016. Consequences of environmental characteristic from livestock and domestic wastes in wetland disposal on ground water quality in Lucknow (India), International Research Journal of Public Environmental Health. 3, (6) 112-119.

116. Kumar A., Narang S., Mehra R., Singh, S., 2015. Assessment of radon concentration and heavy metal contamination in groundwater samples from some areas of Fazilka district, Punjab, India. Indoor and Built Environment. 0, (0) 1–7.

117. Kumar M., Kumari K., Ramanathan A.L., Saxena R., 2007. A comparative evaluation of groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab, India. Environmental Geology. 53, 553–574.

118. Kumar M., Ramanathan A.L., Rahman M.M., Naidu R., 2016. Concentrations of inorganic arsenic in groundwater, agricultural soils and subsurface sediments from the middle Gangetic plain of Bihar, India. Science of the Total Environment. 573, 1103-1114.

119. Kumar M., Ramanathan A.L., Tripathi R., Farswan S., Kumar D., Bhattacharya P., 2017. A study of trace element contamination using multivariate statistical techniques and health risk assessment in groundwater of Chhaprola Industrial Area, Gautam Buddha Nagar, Uttar Pradesh, India. Chemosphere 166, 135-145

120. Kumar S.K., Logeshkumaran A., Magesh N.S., Godson P.S., Chandrasekar N., 2015. Hydro-geochemistry and application of water quality index (WQI) for groundwater quality assessment, Anna Nagar, part of Chennai City, Tamil Nadu, India. Applied Water Science. 5, (4) 335–343.

121. Kumar V.S., Amarender B., Dhakate R., Sankaran S., Kumar K.R., 2014. Assessment of groundwater quality for drinking and irrigation use in shallow hard rock aquifer of Pudunagaram, Palakkad District Kerala. Applied Water Science. DOI 10.1007/s13201-014-0214-6.

122. Kundu M.C., Mandal B., 2009. Agriculture activities influence nitrate and fluoride contamination in drinking groundwater of an intensively cultivated district in India. Water Air, and Soil Pollution. 198, (1-4) 243-252.

123. Lal N.K.P., Karthikeyan K., Praveesh V., Devi V., Suriyanarayanan S., Kumar V.V., 2014. Drinking water quality assessment of ground waters of Bhachau - Kachchh, Gujarat, India with special reference to major anions and cations. International Research Journal of Environment Sciences. 3, (5) 67-72.

124. Landwehr J.M., 1979. A statistical view of a class of water quality indices. Water Resources Research. 15, (2) 460–468.

125. Li P., Qian H., Wu J., Chen J., Zhang Y., Zhang H., 2014. Occurrence and hydrogeochemistry of fluoride in alluvial aquifer of Weihe River, China. Environmental Earth Sciences. 71, 3133–3145.

126. Li P., Wu J., Qian H., Zhang Y., Yang N., Jing L., Yu P., 2016. Hydrogeochemical Characterization of Groundwater in and Around a Wastewater Irrigated Forest in the Southeastern Edge of the Tengger Desert, Northwest China. Expo Health. 8, 331–348.

127. Liou S.M., Lo S.L., Wang S.H., 2004. A generalized water quality index for Taiwan. Environmental Monitoring and Assessment. 96, (1–3) 35–52.

128. Litovitz T.L., (1988). Clinical manifestation of toxicity in a series of 784 boric acid ingestions. American journal of emergency medicine. 31, 209-213.

129. Liu G., Yu Y., Hou J., Xue W., Liu X., Wang W., Alsaedi A., Hyat T., Liu Z., 2014. An ecological risk assessment of heavy metal pollution of the agricultural ecosystem near a lead-acid battery factory. Ecological Indicators. 47, 210-218.

130. Livsmedelsverket fo ¨rfattningssamling 2005. Fo ¨reskrifter om a ¨ndring i Livsmedelsverkets fo ¨reskrifter (SLVFS 2001:30) om dricksvatten, 10.

131. Madhav S., Ahamad A., Kumar, A., Kushawaha J., Singh P., Mishra P.K., 2018. Geochemical assessment of groundwater quality for its suitability for drinking and irrigation purpose in rural areas of Sant Ravidas Nagar (Bhadohi), Uttar Pradesh. Geology, Ecology, and Landscapes. 2, (2) 127–136.

132. Madhnure P, Sirsikar D.Y., Tiwari A.N., Ranjan B., Malpe D.B., 2007. Occurrence of fluoride in the groundwaters of Pandharkawada area, Yavatmal district, Maharashtra, India. Current Science. 92, (5) 675-679.

133. Madhusudhan L., 2015. Agriculture Role on Indian Economy. Business and Economics Journal. 6, 176.

134. Magesh N.S., Chandrasekar N., 2013. Evaluation of spatial variations in groundwater quality by WQI and GIS technique: a case study of Virudunagar District, Tamil Nadu, India. Arabian Journal of Geosciences. 6, 1883–1898.

135. Magesh N.S., Krishnakumar S., Chandrasekar N., Soundranayagam J.P., 2013. Groundwater quality assessment using WQI and GIS techniques, Dindigul district, Tamil Nadu, India. Arabian Journal of Geosciences. 6, (11) 4179–4189.

136. Maitia S.K., Dea S., Hazrab T., Debsarkarb A., Dutta A., 2016. Characterization of Leachate and Its Impact on Surface and Groundwater Quality of a Closed Dumpsite - A Case Study at Dhapa, Kolkata, India. Procedia Environmental Sciences. 35, 391 – 399.

137. Majolagbe A.O., Adeyi A.A., Osibanjo O., Adams A.O., Ojuri O.O., 2017. Pollution vulnerability and health risk assessment of groundwater around an engineering Landfill in Lagos, Nigeria. Chemistry International. 3, (1) 68-68.

138. Mandal P., Kumar S., 2012. Assessment of Groundwater Quality in Industrial Areas of Delhi, India by Indexing Method. Water Quality Monitoring and Assessment, Dr. Voudouris (Ed.), ISBN: 978-953-51-0486- 5, InTech.

139. Mangal M., Agarwal M., Bhargava D., 2013. A Case Study of Impacts of Tannery Effluent of Leather Industry of Manpura Machedi on Ground Water Quality of that Area. Journal of Pharmacognosy and Phytochemistry. 2, (2) 229-233.

140. Manjeet, Singh B.P., Sharma J.K., 2014. Assessment of Quality of Ground Water in Some Villages of Gurgaon District, Haryana (India): Focus on Fluoride. International Journal of Innovative Research in Science, Engineering and Technology. 3, (4) 11441-11448.

141. Mansouri B., Salehi J., Etebari B., Moghaddam H.K., 2012. Metal Concentrations in the Groundwater in Birjand Flood Plain, Iran. Bulletin of Environmental Contamination and Toxicology. 89, 138–142.

142. Matta G., Kumar A., Walia A., Kumar S., Mishra H.K., Dhingra G.K., Pokhriyal P., Wats M., 2016. Quality estimation of Ground water in Industrial estate of Uttarakhand. Pollution Research. 35, (4) 849-854.

143. Mc Quarrie M.C., Lime, 1966. In: McGraw-Hill encyclopaedia of science and technology, New York, McGraw-Hill.

144. McArthur J.M., Sikdar P.K., Hoque M.A., Ghosal U., 2012. Waste-water impacts on groundwater: Cl/Br ratios and implications for arsenic pollution of groundwater in the Bengal Basin and Red River Basin, Vietnam. Science of the Total Environment. 437, 390-402.

145. McFarland M., Lemon R., Stichler C., 2002. L-5417, Irrigation Water Quality, Texas Cooperative Extension, The Texas A & M University System.

146. Mesı ´as M., Seiquer I., Pilar, Navarro M., 2013. Iron nutrition in adolescence. Critical Reviews in Food Science and Nutrition. 53, (11) 1226–1237.

147. Mitra B.K., Sasaki C., Enari K., Matsuyama N., Fujita M., 2007. Suitability assessment of shallow groundwater for agriculture in sand dune area of northwest Honshu Island Japan. Applied Ecology and Environmental Research 5, (1) 177-188.

148. Mohebbi M.R., Saeedi R., Montazeri A., Vaghefia K.A., Labbafia S., Oktaiec S., Abtahi M., Mohagheghianc A., 2013. Assessment of water quality in groundwater resources of Iran using a modified drinking water quality index (DWQI). Ecological Indicators. 30, 28–3.

149. Morrow H., 2001. Cadmium and CadmiumRANI Alloys. *In:* Kirk-Othmer Encyclopedia of Chemical Technology, 5th ed., Vol. 4. New York: John Wiley & Sons, pp. 471–507.

150. Mueller D.K., Hamilton P.A., Helsel D.R., Hitt K.J., Ruddy B.C., 1995. US Geological Survey Water Resources Investigations Report 95-4031, Denver, Colorado.

151. Mulamattathil S.G., Bezuidenhout C., Mbewe M., 2015. Analysis of physico-chemical and bacteriological quality of drinking water in Mafikeng, South Africa. Journal of Water & Health. 13, (4) 1143-1152.

152. Nagarajan R., Rajmohan N., Mahendran U., Senthamilkumar S., 2010. Evaluation of groundwater quality and its suitability for drinking and agricultural use in Thanjavur city, Tamil Nadu, India. Environmental Monitoring and Assessment. 171, (1-4) 289-308.
153. Narsimha A., Sudarshan V., Swathi P., 2013. Groundwater and Its assessment for Irrigation purpose in Hanmakonda Area, Warangal District, Andhra Pradesh, India. International Journal of Research in Chemistry and Environment. 3, (2) 196-200.
154. Nasir M.S., Nasir A., Rashid H., Shah S.H.H., 2017. Spatial variability and long-term analysis of groundwater quality of Faisalabad industrial zone. Applied Water Science. 7, 3197–3205.
155. Naveen B.P., Mahapatra D.M., Sitharam T.G., Sivapullaiah P.V., Ramachandra T.V., 2016. Physico-chemical and biological characterization of urban municipal landfill leachate. Environmental Pollution. http://dx.doi.org/10.1016/j.envpol.2016.09.002
156. Nemerow N.L., Sumitomo H., 1970. Benefits of Water Quality Enhancement, Report No. 16110 DAJ, prepared for the U.S. Environmental Protection Agency. December 1970. Syracuse University, Syracuse, New York.
157. Nezhad A.B., Emamjomeh M.M., Farzadkia M., Jafari A.J., Sayadi M., Davo Udian Talab A.H., 2017. Nitrite and Nitrate Concentrations in the Drinking Groundwater of Shiraz City, South-central Iran by Statistical Models. Iranian Journal of Public Health. 46, (9) 1275-1284.
158. NRC (National Research Council), (1989). Recommended Dietary Allowances, 10th Ed. Washington, D.C.: National Academy Press.
159. Nwankwoala H.O., Nwowo K.N., Udom G.J., 2016. Assessment of Heavy Metal Status of Groundwater in Parts of Aba, Southeastern Nigeria. International Journal of Emerging Engineering Research and Technology. 4, (11), 27-36.
160. Ogoyi D.O., Mwita C.J., Nguu E.K., Shiundu P.M., 2011. Determination of Heavy Metal Content in Water, Sediment and Microalgae from Lake Victoria, East Africa. The Open Environmental Engineering Journal. 4, 156-161.
161. Ogwuegbu M.O.C., Muhanga W., 2005. Investigation of lead concentration in the blood of people in the copperbelt province of Zambia. Journal of Environment. 1, 66–75.

162. Olaoye R.A., Oladeji O.S., 2015. Preliminary Assessment of Effects of Paint Industry Effluents on Local Groundwater Regime in Ibadan, Nigeria. International Journal of Engineering Research. 4, (10) 518-522.

163. Oruko R.O., Moturi W.N., Mironga J.M. 2014. Assessment of tannery based solid wastes management in Asili, Nairobi Kenya, International Journal of Quality Research. 8, (2) 227–238.

164. Paliwal K.V., 1972. Irrigation with saline water. Monogram No. 2, new series (p. 198). New Delhi: IARI.

165. Panaskar D.B., Wagh V.M., Muley A.A., Mukate S.V., Pawar R.S., Aamalawar M.L., 2016. Evaluating groundwater suitability for the domestic, irrigation, and industrial purposes in Nanded Tehsil, Maharashtra, India, using GIS and statistics. Arabian Journal of Geosciences. 9, 615.

166. Pandey G.S., Seth P.S., 1983. Inhabited neutralisation of galvanizing plant effluents by lime stone. Metal and Minerals Review. 22, 59-61.

167. Park Y., Kim Y., Park S.K., Shin W.J., Lee K.S., 2018. Water quality impacts of irrigation return flow on stream and groundwater in an intensive agricultural watershed. Science of the Total Environment. 630, 859-868.

168. Patel K.S., Sahu B.L., Dahariya N.S., Bhatia A., Patel R.K., Matini L., Sracek O., Bhattacharya P., 2017. Groundwater arsenic and fluoride in Rajnandgaon District, Chhattisgarh, northeastern India. Applied Water Science. 7, 1817–1826.

169. Pavendan P., Selvan A.S., Sebastian C., Rajasekaran, 2011. Physico chemical and microbial assessment of drinking water from different water sources of Tiruchirappalli District, South India. European Journal of Experimental Biology. 1, (1) 183-189.

170. Peiyue L., Qian W., Jianhua W., 2011. Groundwater Suitability for Drinking and Agricultural Usage in Yinchuan Area, China. International Journal of Environmental Sciences. 1, (6) 1248-1256.

171. Pittyjohn W.A., 1972. Water quality in a stressed environment, Minnesota, Burgess Publishing Company.

172. Pophali S., Siddiqui S., Khan L.H., 1990. Sources and distribution of heavy metals in the abiotic components of a polluted urban stream in Bhopal, Indian Journal of Environmental Pollution. 10, 600-603.

173. Prakash K.L., Somashekar R.K., 2006. Groundwater quality - Assessment on Anekal taluk, Bangalore urban district, India. Journal of Environmental Biology. 27, (4) 633-637.

174. Prasanth S.V.S., Magesh N.S., Jitheshlal K.V., Chandrasekar N., Gangadhar K., 2012. Evaluation of groundwater quality and its suitability for drinking and agricultural use in the coastal stretch of Alappuzha District, Kerala, India. Applied Water Science. 2, 165–175.

175. Ragunath H.M., 1987. Groundwater (p.563). NewDelhi: Wiley Eastern.

176. Rajankar P.N., Tambekar D.H., Wate S.R., 2011. Groundwater quality and water quality index at Bhandara District. Environmental Monitoring and Assessment. 179, (1-4) 619–625.

177. Rajappa B., Manjappa S., Puttaiah E.T., 2010. Monitoring of Heavy Metal Concentration in Groundwater of Hakinaka Taluk, India. Contemporary Engineering Sciences. 3, (4) 183- 190.

178. Rajasulochana P., Preethy V., 2016. Comparison on efficiency of various techniques in treatment of waste and sewage water – A comprehensive review. Resource-Efficient Technologies. 2, 175–184.

179. Ramesh K., Thirumangai V., 2014. Impacts of Tanneries on Quality of Groundwater in Pallavaram, Chennai Metropolitan City. International Journal of Engineering Research and Applications. 4, (1) 63-70.

180. Ramkrishnaiah C.R., Sadashivaiah C., Ranganna G., 2009. Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry. 6, (2) 523–530.

181. Ramteke D.D., Moghe C.A., 1986. Manual on water and wastewater analysis. NEERI, Nagpur, India.

182. Rani A., Kumar A., Lal A., Pant M., 2014. Cellular mechanisms of cadmium-induced toxicity: a review. International Journal of Environmental Health Research. 24, (4) 378–399.

183. Ranjana A., 2010. Physical-chemical analysis of some ground water sample of Kotputli town Jaipur, Rajastan. International Journal of Chemical, Environmental and Pharmaceutical Research. 1, (2) 111-113.

184. Rao C.S., Rao B.S., Hariharan A.V.L.N.S.H., Bharathi N.M., 2010. Determination of water quality index of some areas in Guntur district Andhra Pradesh.

International Journal of Applied Biology and Pharmaceutical Technology. I, (1) 79–86.

185. Rao N.S., Prasad P.R., 1997. Phosphate pollution in the groundwater of lower Vamsadhara river basin, India. Environmental Geology. 31, (1) 117-122.
186. Ravikumar P., Somashekar R.K., Angami M., 2011. Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India. Environmental Monitoring and Assessment. 173, 459–487.
187. Ravikumar P., Venkatesharaju K., Prakash K.K., Somashekar R.K., 2011. Geochemistry of groundwater and groundwater prospects evaluation, Anekal Taluk, Bangalore Urban District, Karnataka, India. Environmental Monitoring and Assessment. 179, (1-4) 93-112.
188. Rezaei A., Hassani H., 2018. Hydrogeochemistry study and groundwater quality assessment in the north of Isfahan, Iran. Environmental Geochemistry and Health. 40, (2) 583-608.
189. Ribeiro L., Paralta E., Nascimento J., Amaro S., Oliveira E., Salgueiro R., 2002. A agricultura e a delimitac ao das zonas vulnera'veis aos nitratosdeorigem agrı'cola segundo a Directiva 91/676/CE. In: Proc. III Congreso Ibe'rico sobre Gestio'n e Planificacio'n del Agua (pp. 508–513). Universidad de Sevilla, Spain.
190. Richards L.A., 1954. Diagnosis and improvement of saline alkali soils: Agriculture, vole 160. Handbook 60. Washington: US Department of Agriculture.
191. Roadcap G.S., Kelly W.R., Bethke C.M., 2005. Geochemistry of extremely alkaline (pH 12) ground water in slag-fill aquifers. Ground Water. 43, (6) 806-816.
192. Sadat-Noori S.M., Ebrahimi K., Liaghat A.M., 2014. Groundwater quality assessment using the Water Quality Index and GIS in Saveh-Nobaran aquifer, Iran. Environmental Earth Sciences. 71, (9) 3827-3843.
193. Saeedi M., Abessi O., Sharifi F., Meraji H., 2010. Development of groundwater quality index, Environmental Monitoring and Assessment. 163, (1-4) 327-335.
194. Saha N., Rahman M.S., Ahmed M.B., Zhou J.L., Ngo H.H., Guo W., 2017. Industrial metal pollution in water and probabilistic assessment of human health risk, Journal of Environmental Management. 185, 70-78.
195. Said A., Stevens D.K., Sehlke G., 2004. Environmental assessment: an innovation index for evaluation water quality in streams. Environmental Management. 34, (3) 406–414.

196. Saleh S.M.K., Al-Alaiy S.H.G., Abdul-Razzak B.I., Nasher G.S.H., 2017. Evaluation of groundwater quality and its suitability for drinking and agricultural use of rural areas for Zabid Directorate Wadi Zabid, Hodiedah, Yemen. Journal of Scientific and Engineering Research. 4, (7) 10–24.
197. Salifu M., Aidoo F., Hayford M.S., Adomako D., Asare E., 2017. Evaluating the suitability of groundwater for irrigational purposes in some selected districts of the Upper West region of Ghana. Applied Water Science. 7, 653–662.
198. Saritha B., Chockalingam M.P., 2018. Evaluation and Characterization of Tannery Wastewater. International Journal of Pure and Applied Mathematics. 119, (12) 8479-8487.
199. Schepers J.S., Moravek M.G., Alberts E.E., Frank K.D., 1991. Maize production impacts on groundwater quallity. Journal of Environmental Quality. 20, (1) 12-16.
200. Schullehner J., Stayner L., Hansen B., 2017. Nitrate, Nitrite, and Ammonium Variability in Drinking Water Distribution Systems. International Journal of Environmental Research and Public Health. 14, 276.
201. Scottish Development Department, 1975. Towards cleaner water. Edinburgh: HMSO, Report of a River Pollution Survey of Scotland.
202. Sekhon G.S., Singh B., 2013. Estimation of Heavy Metals in the Groundwater of Patiala District of Punjab, India. Earth Resources. 1, (1) 1-4.
203. Selvakumar S., Chandrasekar N., Kumar G., 2017. Hydrogeochemical characteristics and groundwater contamination in the rapid urban development areas of Coimbatore, India. Water Resources and Industry. 17, 26-33.
204. Sharma D., Kansal A., 2011. Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000–2009). Applied Water Science. 1, (3–4) 147–157.
205. Sharma R.A., 2014. Report on groundwater quality studies in Malwa region of Punjab, Muktsar. International Journal of Engineering Research and Applications. 4, (12) 70-77.
206. Sharma S., Chhipa R.C., 2016. Seasonal variations of ground water quality and its agglomerates by water quality index. Global Journal of Environmental Science and Management. 2, (1) 79-86.
207. Singh A.K., Tewary B.K., Sinha A., 2011. Hydrochemistry and quality assessment of groundwater in part of NOIDA metropolitan city, Uttar Pradesh. Journal of Geological Society of India. 78, (6) 523–540.

208. Singh A.L., Singh V.K., 2018. Assessment of groundwater quality of Ballia district, Uttar Pradesh, India, with reference to arsenic contamination using multivariate statistical analysis. Applied Water Science. 8, 95.

209. Singh B., Sekhon G.S., 1976. Nitrate pollution of groundwater from nitrogen fertilizers and animal wastes in the Punjab, India. Agriculture and Environment. 3, (1) 57–67.

210. Singh K., Singh D., Hundal H.S., 2013. An appraisal of groundwater quality for drinking and irrigation purposes in southern part of Bathinda district of Punjab, northwest India. Environmental Earth Science. 70, 1841–1851.

211. Singh S., Hussian A., 2016. Water quality index development for groundwater quality assessment of Greater Noida sub-basin, Uttar Pradesh, India. Cogent Engineering. 3, 117755.

212. Singh U.V., Abhishek A., Singh K.P., Dhakate R., Singh N.P., 2014. Groundwater quality appraisal and its hydrochemical characterization in Ghaziabad (a region of indo-gangetic plain), Uttar Pradesh, India. Applied Water Science. 4, 145–157.

213. Singh V.B., Tripathi J.N., 2016. Identification of critical water quality parameters derived from principal component analysis: case study from NOIDA area in India. American Journal of Water Resources. 4, (6) 121-129.

214. Singh V.K., Ramprakash, Rajpaul, Kumar S., Singh K., Satyavan, 2017. Evaluation of Groundwater Quality for Irrigation in Gulha Block of Kaithal District in Haryana. Journal of Soil Salinity and Water Quality 9, (2) 241-248.

215. Sittig M., 1979. Hazardous and Toxic Effects of Industrial Chemicals, Noyes Data Corporation, Park Ridge, New Jersey, U.S.A.

216. Smedley P.L., Kinniburgh D.G., 2002. A review of the source, behavior and distribution of arsenic in natural waters. Applied Geochemistry. 17, (5) 517–568.

217. Soleimani H., Abbasnia A., Yousefi M., Mohammadi A.A., Khorasgani F.C., 2018. Data on assessment of groundwater quality for drinking and irrigation in rural area Sarpol-e Zahab city, Kermanshah province, Iran. Data in Brief. 17, 148–156.

218. Spalding R.F., Exner M.E., 1993. Occurrence of nitrate in groundwater- a review. Journal of Environmental Quality. 22, (3) 392-402.

219. Spruill T.B., Harned D.A., Ruhl P.M., Eimers J.L., McMahon G., Smith K.E., Galeone D.R., Woodside M.D., 1998. Water quality in the Albemarle-Pamlico drainage basin, North Carolina and Virginia, 1992-95. No. 1157. US Dept. of the

Interior, US Geological Survey; Free on application to the US Geological Survey, Information Services.

220. Srinivas, Piska R.S., Reddy R.R., 2002. Ground water pollution due to the industrial effluents in Kothur industrial area, Mahaboobnagar, Andhra Pradesh, India. Ecology, Environment and Conservation. 8, (4) 377- 380.

221. Srivastava N.K., Majumder C.B., 2008. Novel biofiltration methods for the treatment of heavy metals from industrial wastewater. Journal of Hazardous Materials. 151, (1) 1-8.

222. Stambuk-Giljanovic N., 1999. Water quality evaluation by index in Dalmatia. Water Resources. 33, (16) 3423–3440.

223. Stokinger H.E., 1981. Boron. In: Clayton GD, Clayton FE, eds. Patty's industrial hygiene and toxicology. Vol. 2B. Toxicology, 3rd ed. New York, NY, John Wiley & Sons, pp. 2978- 3005.

224. Stumm W., Lee G.F., 1960. The Chemistry of aqueous iron. Schweiz. Z. Hydrol., 22, 295-319.

225. Suhag R., 2016. Overview of Ground Water in India, Standing Committee on Water Resources.

226. Sunitha V., Reddy B.M., Khan J.A., Raj R.S., Reddy B.S., Richardson C.S., 2014. Assessment of Groundwater Quality of Kalasapadu, Porumamilla Mandals, Kadapa, Y.S.R District, India. Journal of Chemical, Biological and Physical Sciences. 4, (1) 787-796.

227. Suthar S., Bishnoi P., Singh S., Mutiyar P.K., Nema A.K., Patil N.S., 2009. Nitrate contamination in groundwater of some rural areas of Rajasthan, India. Journal of Hazardous Materials. 171, (1-3) 189-199.

228. Swamee P.K., Tyagi A., 2000. Describing water quality with aggregate index. Journal of Environmental Engineering. 126, (5) 451–455.

229. Tambekar D.H., Neware B.B., 2012. Water quality index and multivariate analysis for groundwater quality assessment of villages of rural India. Science research reporter. 2, (3) 229-235.

230. Tariq S.R., Shah M.H., Shaheen N., Jaffar M., Khalique A., 2008. Statistical source identification of metals in groundwater exposed to industrial contamination. Environment Monitoring and Assessment. 138, (1-3) 159-165.

231. Tay C., 2004. Report on the ground water quality of Akatsi and Ketu districts in the Volta region of Ghana. CSIR – WRI. West African Journal of Applied Ecology. 11:3-25.
232. Todd D.K., 1959. Groundwater hydrology (p. 535). New York: Wiley.
233. Trivedy R.K., Goyal P.K., 1986. Chemical and Biological methods for water pollution studies. Envtal. Toxi. Enviro-Media Karad: pp: 3-34, 36-96.
234. Tyagi S.K., Datta P.S., Pruthi N.K., 2009. Hydrochemical appraisal of groundwater and its suitability in the intensive agricultural area of Muzaffarnagar district, Uttar Pradesh, India. Environmental Geology. 56, 901–912.
235. Udedi S.S., 2003. From guinea worm scourge to metal toxicity in Ebonyi State. Chemistry in Nigeria as the New Millennium Unfolds 2, (2) 13–14.
236. Ullah R., Malik R.N., Qadir A., 2009. Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan. African Journal of Environmental Science and Technology. 3, (12) 429-446.
237. Vasanthavigar M., Srinivasamoorthy K., Vijayaragavan K., Ganthi R.R., Chidambaram S., Anandhan P., Manivannan R., Vasudevan S., 2010. Application of water quality index for groundwater quality assessment Thirumanimuttar sub-basin, Tamilnadu, India. Environment Monitoring and Assessment. 171, (1-4) 595-609.
238. Vetrimurugan E., Brindha K., Elango L., Ndwandwe O.M., 2017. Human exposure risk to heavy metals through groundwater used for drinking in an intensively irrigated river delta. Applied Water Science. 7, 3267–3280.
239. Walski T.M., Parker F.L., 1974. Consumers water quality index. Journal of Environmental Engineering Division. 100, (3) 593–611.
240. Wang S., 2013. Groundwater quality and its suitability for drinking and agricultural use in the Yanqi Basin of Xinjiang Province, Northwest China. Environmental Monitoring and Assessment. DOI 10.1007/s10661-013-3113-7.
241. Wilcox L.V., 1955. Classification and use of irrigation waters, US Dept of Agriculture, Circular No. 969, PP 19, Washington, DC.
242. Wirmvem M.J., Ohba T., Nche L.A., Kamtchueng B.T., Kongnso W.E., Mimba M.E., Bafon T.G., Yaguchi M., Takem G.E., Fantong W.Y., Ako A.A., 2017. Effect of diffuse recharge and wastewater on groundwater contamination in Douala, Cameroon. Environmental Earth Science. 76, 354.

243. Wist W., Lehr J.H., McEachern R., 2009. Water Softening with Potassium Chloride: Process, Health, and Environmental Benefits. John Wiley & Sons, Inc.
244. World Health Organization (WHO), 2017. Guidelines for drinking-water quality, (4th edition incorporating the first addendum), World Health Organisation, Geneva.
245. Wosnie A., Wondie A., 2014. Assessment of downstream impact of Bahir Dar tannery effluent on the head of Blue Nile River using macroinvertebrates as bioindicators. International Journal of Biodiversity and Conservation. 6, (4) 342-350.
246. Wu J., Sun Z., 2016. Evaluation of Shallow Groundwater Contamination and Associated Human Health Risk in an Alluvial Plain Impacted by Agricultural and Industrial Activities, Mid-west China. Exposure and Health. 8, 311–329.
247. Youcai Z., 2018. Chapter-1 Leachate Generation and Characterstics, Book-Pollution Control Technology for Leachate from municipal Solid Waste.
248. Zhang Y., Wu J., Xu B., 2018. Human health risk assessment of groundwater nitrogen pollution in Jinghui canal irrigation area of the loess region, northwest China. Environmental Earth Science. 77, 273.

Chapter 6

REMOVAL OF FLUORIDE FROM AQUEOUS SOLUTION

The physico-chemical analysis of groundwater was done during the research period (2016-2018). The concentration of fluoride in nearly 10.6% of analysed samples exceeded the acceptable limit and three samples of industrial zone (Achheja & Dujana) were above the permissible value of BIS. Even if the concentration of fluoride was not profoundly analysed in water samples collected from different water quality stations of GBN district but fluoride removal was taken as one of the remediation method as per the availability of resources and sustainable solution of reutilization of by-product of marble industry. Marble slurry generated from the industry was utilized for analysis here.

In current study, an initiative has been taken for fluoride removal with the help of marble slurry (MS) as a suitable and cost-effective adsorbent. According to recent census, marble reserves of India is projected to be about twelve hundred million tons. Marble slurry is produced during the manufacture of marble. The adverse environmental effects of marble slurry are as follows:

- Marble slurry leads to extreme reduction of permeability and filtration of topsoil, which over a period can lead to water logging problems at the surface. This has resulted in a rapid decline of underground water level. Marble slurry also increases the alkalinity of soil thereby decreasing the fertility of the soil.
- When dried, marble slurry gets suspended in the air as fine dust. It slowly dispersed over large areas effecting harvests and vegetation causing severe ecological threats.

6.1 LITERATURE REVIEW

Fluoride is vital for the prevention of cavities but if overdosed it can lead to adverse health effects. If taken in excess amount it can lead to fluorosis of bones/teeth (Sorg, 1978; Mahramanlioglu et al., 2002). Amassing over large periods of time or large dosages can lead to a structural change in DNA as well (Tsutsui et al., 1984; Wang et al., 2004). Excessive fluoride concentration in underground water is a persistent problem for regions like Asia, Africa and USA (Lee et al., 1995; Naoki et al., 1996; Mameri et al., 1998). India is also among the most affected countries along with China for excessive fluoride concentrations. An overwhelming amount of 14.1% fluoride concentration is deposited on the lands of India. Hence, 17 states in India are indigenous to fluorosis (UNICEF, 1999). This higher fluoride concentration is due to the igneous and metamorphic rocks in the Indian subcontinent. The problem of fluorosis is rather prominent in the states like Rajasthan, Tamil Nadu, Bihar, Gujarat, Andhra Pradesh, Kerala, Telangana, Punjab and Uttar Pradesh (Hussain et al., 2002; Hussain et al., 2004; Husain et al., 2010; Arif et al., 2012; Husain et al., 2012; Sneha et al., 2012; Arif et al., 2013; Husain et al., 2013; Adimalla & Venkatayogi, 2016; Narsimha & Sudarshan, 2017; Raj & Shaji, 2017; Podgorski et al., 2018; Adimalla et al., 2019). According to a census conducted by department of Drinking Water Supply under ministry of Rural Development, India, around 85% population of rural India is dependent on underground water. Therefore, due to such an excessive demand, removal of excessive fluoride ion concentration to a level of 1.5 mg/L (according to BIS) becomes necessary (WHO, 2006).

This limit varies with different countries with different age groups. The World Health Organisation has set a standard value of fluoride ion concentration of 1.5 mg/L whereas in United States of America the standard limit is set between 0.6-0.9 mg/L (US Public Health Service Drinking Water Standards, 1962). Because of the pestilential effects of fluoride to humanity and its availability in the drinking water, there is a grave need to check the fluoride concentrations so that it becomes safe for human consumption.

Defluoridation techniques are of two types depending upon their mechanism; Membrane techniques & Adsorption techniques (Parthasarathy et al., 1986; Saha, 1993; Haron et al., 1995; Qureshi et al., 1995). Many processes are recently investigated which included reverse-osmosis, dialysis and nano-filtration. In India, Nalgonda technique is generally used because of its cost-effectiveness and clarity. For small sections, adsorption is considered as an exemplary technique for the process of defluoridation.

6.1.1 Membrane Techniques

Membrane techniques include reverse osmosis, nano-filtration, dialysis and electro-dialysis.

- **Reverse osmosis and Nano-filtration**

The process of reverse osmosis and nano-filtration are highly capable (Schneiter & Middlebrooks, 1983). More than 98% removal efficiency of fluoride ions was reported by Arora, (2004). A solar powered NF/RO system was used in a school in northern Tanzania for the removal of excess of fluoride (47.6 mg/L) from groundwater (Shen et al., 2016). They prepared four membranes- BW30, BW30-LE (RO membranes) & NF90, NF270 (NF membrane). Study concluded that NF90 membrane was best suitable for fluoride removal. System was able to filter 1582 litre/day of water, through NF90 membrane, to safe drinking water.

Nano filtration and reverse osmosis is based upon same principles however for nano-filtration pore size of membranes is slightly larger than that of reverse osmosis. Nano-filtration has some advantages over reverse osmosis-

- Less resistance for flow of solute/solvent
- Less pressure required
- Less energy consumption
- High flow rate

Being a small ion, fluoride ion is strongly hydrated than any other monovalent ion present in water and hence easily retained by membranes. Membranes can be used single or in combinations. Experimental conditions (contact time, pressure exerted, fluoride concentration etc.) affect the efficiency of membranes (Mohapatra et al., 2009; Ayala et al., 2018).

- **Dialysis and Electro-dialysis**

Dialysis separates ions from aqueous solution through a membrane. Actually membrane does not work as a filter as water does not pass through it. Two types of driving force can be applied to solute particles; the Donnan effect or an applied electric field. Grames et al., (2002) combined donnan dialysis with adsorption process (adsorbent Al_2O_3 + ZrO_2). The combined process brought the fluoride level of mine water from 4 mg/L to acceptable limit of BIS (1.5 mg/L). The anion exchange membrane used in process was Neosepta-ACS. Durmaz et al., (2005) used Neosepta AHA anion exchange membrane for defluoridation of water. They also compared the efficiency of Neosepta AHA membrane with Neosepta AFN and polysulfone SB-6407 membranes and concluded that Neosepta AHA was more efficient than polysulfone SB-6407 membranes but less efficient than Neosepta AFN. Alkan et al., (2008) and Boubakri et al., (2014) also used Donnan dialysis for defluoridation of water.

Electro-dialysis is the removal of ionic components from aqueous solutions through ion exchange membranes under the driving force of an electric field. The electro-dialysis process was used for the defluoridation of sub-surface water in Africa. From this technique, initial fluoride content (>30 mg/L) of water can be brought upto 1.5 mg/L (Hichour et al., 1999). Results of study revealed that maximum defluoridation occurred at pH 6 of feed phase and at pH 1 of receiver phase. Annouar et al., (2004) compared two techniques of defluoridation of aqueous solution; chitosan as an adsorbent and electro-dialysis process. Results showed that electro-dialysis technique was very effective for defluoridation of water with 3000 mg/L TDS and 3 mg/L fluoride concentration. Tahaikt et al., (2006) studied defluoridartion of Moroccan groundwater by using electro-dialysis method. The electrodialysis operations were carried out with two anion exchange membranes, Neosepta ACS & AXE 01 membranes and one cation exchange membrane Neosepta CMX.

6.1.2 Adsorption Techniques

Present day many adsorbents are being used for the process of defluoridation such as bone charcoal, lime, alum, aluminium phosphate, fly ash, silica gel, activated alumina, zeolite, anode soil, dolomite, activated carbon, rare earth oxides and cost-cutting adsorbents (such as clay charcoal, woo charcoal, calcite, saw dust, rice, tree bark and ground nut husk) (Zhang & Liang, 1992; Lai & Liu, 1996; Zevenbergen et al., 1996; Bulusu & Nawlakhe, 1988; Srimurali et al., 1998; Ramos et al., 1999; Castel et al., 2000; Lounici et al., 2001; Raichur & Basu 2001; Li et al., 2001; Reardon & Wang 2001; Cengeloglu et al., 2002; Agarwal et al., 2003; Fan et al., 2003; Abe et al., 2004; Mohapatra et al., 2004; Tripathy et al., 2004; Ghorai & Pant, 2005; Ahamad et al., 2019). These commonly used techniques are based on the mechanism of adsorption. But the efficiency of the cost-cutting adsorbents (eg. red mud, zeolites and alum sludge) declines sharply under brackish conditions. In addition, the adsorption process is highly pH specific. In case of acidic conditions (pH<3) sorption process is the most effective but at a natural process desorption of fluoride takes place (Srimurali et al., 1998). Other complexes like activated carbon and various oxides of rare earth materials are effective adsorbents but because of their high cost, their usage is hindered (Ho et al., 2004).

Adsorption of fluoride ion on adsorbent surface follow three steps (Fan et al., 2003):

- Transfer of solute particles from aqueous solution to the outer surface of adsorbent.
- Adsorption of solute particles on the surface of adsorbent.
- Adsorbed solute particles get exchanged with the molecules of adsorbent or enters into porous structure of adsorbent.

Various factors are responsible for deciding the suitability of an adsorbent for a particular ion. Adsorption capacity of an adsorbent depends upon pH of solution, contact time of adsorbent & adsorbate, stability of adsorbent, regeneration of adsorbent, initial amount of solute, and presence of other ions. Discussion of various relevant adsorbents was added here.

➢ Alumina and Aluminum based adsorbents

The fluoride removal efficiency of alum-impregnated activated alumina (A/AA) was studied by Tripathy et al., (2004). They concluded that adsorbent worked best (92.6%) at adsorbent dose of 8 gm/L, pH 6.5, contact time of 3 hrs, and initial fluoride concentration of 25 mg/L. Tang et al., (2008) studied the fluoride removal efficiency of activated alumina. They concluded that adsorbent worked well over a range of pH 5 - 10.5 and 1-10 mg F/g adsorbent. Similar type of studies were done by Leyva-Ramos et al., 2008; Stewart, 2009; Karthikeyan et al., 2018 etc.

Maliyekkal et al., (2006) studied the adsorption capacity of manganese oxide coated alumina (MOCA) and concluded that as compared to activated alumina, MOCA showed much better efficiency of fluoride removal (activated alumina- 1.08 mg/g; MOCA- 2.85 mg/g). Tripathy & Raichur, (2008) also analysed the fluoride adsorption behaviour of manganese oxide coated alumina through batch experiments. The results of study revealed that maximum adsorption took place at pH-7, adsorbent dose of 8 g/L and equilibrium attained after 3 hrs. The efficiency of activated alumina can also be enhanced by calcination with magnesium hydroxide at 450^0C (Maliyekkal et al., 2008). Similar type of study was carried out by Lv et al., 2007. Singh et al. (2018) prepared two variants of calcium magnesium activated alumina; CMAA 650 and CMAA 850. They concluded that CMAA 850 showed better removal efficiency of fluoride than CMAA 650.

A novel approach has been made by Chubar et al., (2005) to prepare iron-aluminium double hydrous oxide for defluoridation of aqueous solution. Biswas et al., (2007) also reported synthesis of iron-aluminium mixed oxide and its behaviour for fluoride ion removal. Prepared adsorbent showed highly porous structure, high surface area and irregular surface morphology.

➢ Alumina plus calcium minerals/ Nalgonda technique

The Nalgonda technique, is most popular technique for fluoride removal in India, Kenya, Ethiopia, Tanzania etc. In this technique, alum (Aluminum sulphate or potassium Aluminum sulphate) and lime (calcium oxide) are rapidly mixed with the fluoride-rich water. A portion of fluoride present in water precipitate out and comes to the surface with flocs of aluminium hydroxide (Nawlakhe et al., 1975). For household purpose, a dose of 12.8 gms alum and 6.4 gms lime is sufficient for 20 litre of water. After treatment, fluoride concentration of water comes upto 0.7 – 2.1 mg/L. Although Nalgonda process is very popular but has some demerits:

- Efficiency of process is not very high as it precipitate out only 18-33% of fluoride, rest is converted into soluble form (Apparao & Kartikeyan, 1986).
- Addition of alum as coagulant added the excess of sulphate ions in drinking water. Sometimes after treatment, sulphate ion concentration of water reaches upto 400 mg/L.
- Aluminium content of water also increased (upto 200 µg/L) after treatment causing adverse health effects.
- Water aesthetics also changed after treatment.
- Due to effect of seasonal variations on fluoride concentration of water, monitoring of input and output water is required at regular intervals of time. Monitoring of quality of water decides the required amount of coagulant for treatment of water.
- Treatment plant needs assistance.
- Large area is required for installation of treatment plant.
- Presence of silicates in water adversely effected defluoridation efficiency of treatment plant.

Yami et al., (2018) studied improvement in efficiency of Nalgonda technique in Rift valley of Ethiopia. This study has shown that the performance of the Nalgonda system was significantly enhanced by adding aluminum hydroxide and cow bone char powder into the existing Nalgonda system.

- **Aluminium modified Graphene oxide**

Rajput et al., (2018) synthesized aluminium modified graphene oxide. Optimum conditions required for the maximum removal of fluoride from drinking water were analysed through batch experiments. Results of analysis confirmed that maximum fluoride adsorption capacity of graphene oxide composite was 38.31 mg/gm at the adsorbent dose of 1 gm/L.

- **Bauxite**

Fluoride removal efficiency of thermally activated titanium-rich bauxite (TRB) was investigated by Das et al., (2005). The optimum conditions for maximum fluoride ion removal were thermal activation at 300-450^{0}C, contact time of 90 minutes, pH- 5.5-6.5.

- **Calcium**

Fan et al., (2003) have compared fluoride removal capacity of various low cost materials (fluorspar, quartz, iron activated quartz, hydroxyapatite, calcite) and concluded that fluoride uptake of hydroxyapatite was maximum among the analysed materials.

Wong & Stenstron, (2017) investigated the on-site removal of fluoride from drinking water using calcium carbonate as low cost adsorbent. It can reduce the fluoride concentration from 10 mg/L to less than 1.5 mg/L. Results of batch experiments also showed that equilibrium attained after 180 minutes. Study proved that efficiency of calcium carbonate was comparable to synthetic ion-exchange resins, eggshells and seashells.

- **Carbon Nanotubes**

Dehghani et al., (2016) studied removal of fluoride from aqueous solution through multi-walled and single-walled carbon nanotubes. Results of study revealed that equilibrium reached after contact time of 30 mins. Maximum fluoride removal occurred at acidic pH of 5.

Asimeng et al., (2018) had prepared a novel hydroxyapatite material from Achantia achatina snail for the removal of fluoride from drinking water. Results showed that equilibrium reached after 60 mins. The study concluded that adsorbent was effective for defluoridation from 20 mg/L to 1.59 mg/L.

- **Low cost adsorbents**

Bhargava & Killedar, (1995) examined the conditions required for maximum adsorption of fluoride ions on fish-bone charcoal. Srimurali et al., (1998) examined the removal of fluoride using low-cost materials such as kaolinite, bentonite, charfines, lignite and nirmali seeds and concluded that order of removal efficiency of various adsorbents were; nirmali seeds < lignite < kaolinite < charfines < bentonite.

A phyllosilicate mineral montmorillonite was used for defluoridation of water by Agarwal et al., (2002); Tor, (2006). Fluoride removal from aqueous solution was studied using pine wood & pine bark chars (Mohan et al., 2012). Maximum fluoride removal was attained at pH 2, contact time of 48 hours and adsorbent dose of 10 gm/L.

Saikia et al., (2017) experimented on low cost ceramic nodules prepared from locally available material of Assam. Mahmoudi et al., (2019) studied fluoride removal capacity of acid treated clinoptilolite. Highest removal efficiency of 87% was obtained at pH-3 and contact time of 2 hrs. Xia et al., (2019) studied defluoridation of water by using an adsorbent prepared from boiling egg shells with NaH_2PO_4 and acetic acid. They transformed high fluoride rich water (10 mg/L) into safe drinking water (< 1.5 mg/L).

6.2 HEALTH EFFECTS

Fluoride concentration can have beneficial as well as adverse health effects depending upon the amount of dosage. Fluoride concentration when below the concentration of 1.5 mg/L is favourable for infants for the calcification of dental enamel. Fluoride ion, since it is the most electronegative ion, has a strong affinity towards positive ions like calcium. Hence, fluoride has a substantial effect on calcium containing tissues like bones and teeth. The fluoride gets deposited on teeth and bones in the form of calcium fluorapatite crystals. The main constituents of teeth enamel is calcium hydroxyapatite. When ingested through potable water, the fluoride ion concentration get incorporated into the apatite crystal lattice of calciferous tissue enamel. Afterwards the hydroxyl ions get substituted by fluoride ions from hydroxyapatite to form fluorapatite because the latter is more stable than the former. The mechanism of formation of fluorapatite is knows as fluorosis and it is the major complication regarding excessive fluoride intake. When the severity of excessive fluoride concentration is limited to teeth only it is called dental fluorosis whereas when the skeleton bones are also affected it leads to a condition known as skeletal fluorosis. Both skeletal and dental fluorosis has been a hurdle for many countries globally. The symptoms of dental fluorosis include chipping and perforation of teeth. In the case of skeletal fluorosis, it can lead to extreme discomfort in the joints, which can further lead to paralysis. Modern studies have shown that high amount of fluoride intake can not only lead to skeletal and dental fluorosis but also gastronomical, neurological, muscular and allergic disorders. It may also lead to fatal diseases like cancer.

6.3 MATERIAL AND METHODS

6.3.1 Reagent and Standard Solution

Stock Solution (1000 mg/L fluoride) - 221 mg of sodium fluoride (Merck Germany) dissolved in 100ml of distilled water. Spiked fluoride and standard solutions were made by appropriate dilutions. The level third total ionic strength adjustment (TISAB - Ⅲ) were made according to appropriate procedures (APHA, 2017).

6.3.2 Instrumentation

Fluoride ion concentration was measured with the help of pH/ISE (Orion Ion meter) equipped with the combination of fluoride selective electrode. The fluoride ion electrode was standardized before each analysis in order to determine the slope. For pH measurement, pH glass electrode was used. Whenever the measurements were done by pH standardised buffers, the meter was calibrated.

6.3.3 Batch Experiments

Batch experiments were done to assess the influence of initial concentration of fluoride ions in aqueous solution, adsorbent dosage, pH levels, contact time and co-existing anions. The high concentration fluoride water was stirred along with marble slurry using a mechanical stirrer. Afterwards, the solution was kept for settling. Fluoride concentration of aqueous solution was analysed before and after treatment.

6.4 RESULTS AND DISCUSSION

6.4.1 Influence of Initial Fluoride Concentration on Defluoridation

Fluoride water of different concentration (1.5, 2.5, 3.5, 4.5, 5.5, 6.5 & 7.5 mg/L) were taken for batch experiment. Different batch experiments were conducted to study the influence of initial fluoride concentration on percentage removal of fluoride. Other factors such as adsorbent dose of 15 mg/L, pH – 7 and contact time of 50 minutes were kept constant. The results of experiments are given in Table – 6.1. From the results, it is concluded that with the effect of increase in initial concentration of fluoride ions, the efficiency of adsorbent to remove fluoride ion decreased. Fluoride removal was 89.3% when initial fluoride concentration was 1.5 mg/L, which further decreased to 64% at fluoride concentration of 4.5 mg/L and simultaneously to 40% at 7.5 mg/L fluoride (Fig. 6.1). From the results of study, it is concluded that the binding capability of the adsorbent shift towards the saturation point at higher adsorbate concentration, thereby decreasing the efficiency of defluororsis. Decreased rate of defluoridation, particularly at higher fluoride concentration level proves the formation of a single layer of fluoride ions on the outer surface.

Table - 6.1 Effect of Initial Concentration of Fluoride on Defluoridation

Contact Time = 50 Min., Dose of Adsorbent (gm/L) = 15.0, pH= 7

S. No.		1	2	3	4	5	6	7
Initial Concentration of Fluoride (mg/L)		1.5	2.5	3.5	4.5	5.5	6.5	7.5
Final Concentration of Fluoride (mg/L)		0.16	0.43	0.92	1.62	2.25	3.69	4.51
Fluoride Removal	**mg/L**	1.34	2.07	2.58	2.88	3.25	2.81	2.99
	% Decrease	89.3%	82.8%	73.7%	64.0%	59.1%	43.2%	39.9%

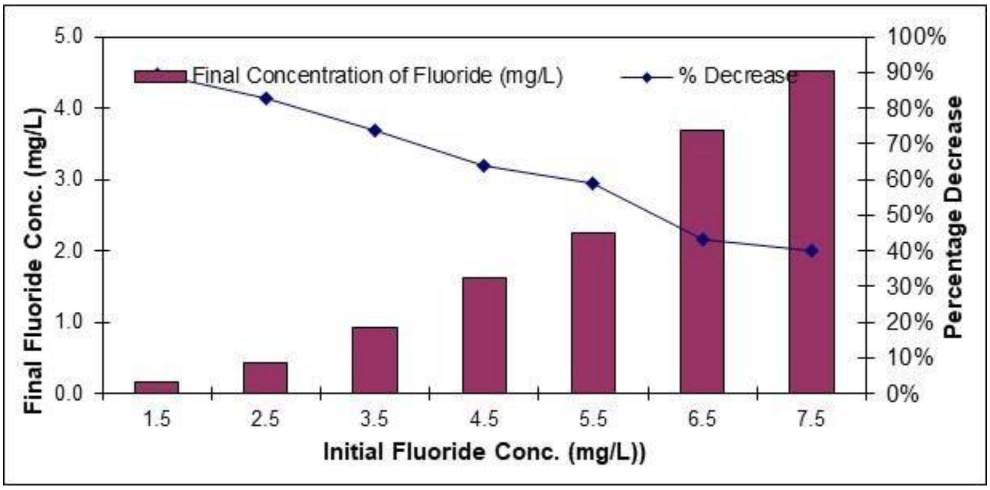


Fig. 6.1 Effect of initial fluoride concentration on Defluoridation

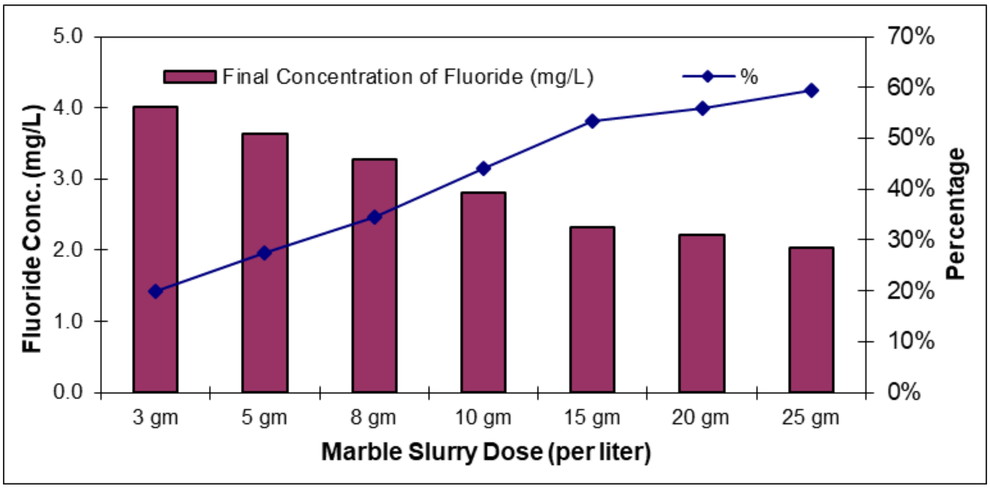
6.4.2 Effect of Marble Slurry Dosage on Defluoridation

Experiments were conducted in order to study the effect of marble slurry dosage on efficiency of defluororsis. Several doses of marble slurry adsorbent (i.e., 3.0, 5.0, 8.0, 10.0, 15.0, 20.0 and 25.0 gms) were taken for the experiments and the fluoride concentration was set to 5 mg/L at 7 pH with contact time of 50 minutes. The results are compiled in Table – 6.2 and Fig. 6.2. It was observed that the efficiency of defluorosis increases with the dosage of adsorbent because of the availability of large surface area and pore volume for adsorption. After a certain amount of adsorbent dose further increase in defluorosis was insignificant due the non-adsorbability of fluoride ions.

Table – 6.2 Effect of Dose of Marble Slurry on Defluoridation

Contact Time = 50 Min., Initial Fluoride Concentration (mg/L) = 5.0, pH = 7

S. No.		1	2	3	4	5	6	7
Dose of Marble Slurry (gm per liter)		3	5	8	10	15	20	25
Final Concentration of Fluoride (mg/L)		4.01	3.63	3.28	2.80	2.33	2.21	2.03
Fluoride Removal	**mg/L**	0.99	1.37	1.72	2.20	2.67	2.79	2.97
	%	19.8%	27.4%	34.4%	44.0%	53.4%	55.8%	59.4%



6.4.3 Effect of Contact Time on Defluoridation:

For the study of influence of contact time on defluoridation, the experiments were carried out on 5 mg/L fluoride concentration water with 15 gm dosage of adsorbent at pH 7. Several contact times (20, 30, 40, 50, 60, 70 and 80 minutes) were taken for the experiments and the conclusions are summed up in Table - 6.3. On increasing the contact time from 20 to 50 minutes, the efficiency of defluorosis increases from 44.8% to 72.4%. However, after 50 minutes of contact time, the rate of defluorosis became constant denoting the attainment of equilibrium (Fig. 6.3). The initial rate of defluorosis increases at a rapid rate due to availability of the vacant pores of the adsorbent. As the vacant sites, get occupied, the rate of adsorption leads to equilibrium.

Table - 6.3 Effect of Contact Time with Marble Slurry on Defluoridation

Marble Slurry Dose = 15 gm/L, Initial Fluoride Concentration (mg/L) = 5.0, pH = 7

S. No.		1	2	3	4	5	6	7
Contact Time (Min.)		20	30	40	50	60	70	80
Final Concentration of Fluoride (mg/L)		2.76	2.33	2.00	1.43	1.20	1.16	1.14
Fluoride Removal	**mg/L**	2.24	2.67	3.00	3.62	3.80	3.84	3.86
	%	44.8%	53.4%	60.0%	72.4%	76.0%	76.8%	77.2%

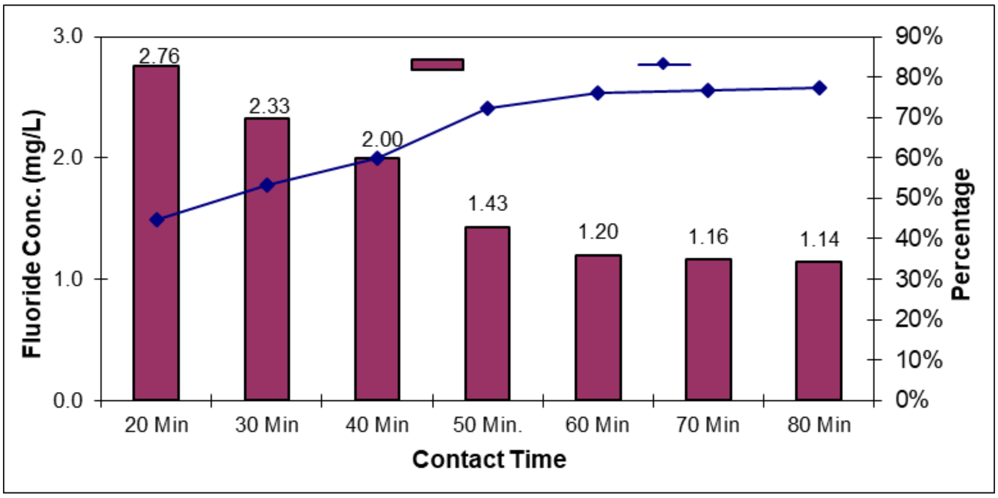


Fig. 6.3 Effect of contact time on Defluoridation

6.4.4 Effect of pH on Defluoridation

For the study of influence of pH on deflurorosis, experiments were carried out in the pH range of 4.16-8.96 and the results are shown in Table – 6.4. The desired pH was attained by standardised 0.1 N sodium hydroxide or 0.1 N hydrochloric acid solutions. Maximum defluorosis (44 - 44.4%) was attained in the pH range of 6.12-7.01. The rate of defluorosis declined at a pH below 6.12 and above pH 7.01 (Fig. 6.4). This is observed because at a pH below 6.12, formation of hydrofluoric acid takes place, which is feebly ionized, resulting in non-availability of free fluoride ions for adsorption. Similarly, at a higher pH, due to the formation OH^- ions, less adsorption of fluoride ions takes place. OH^- ions causes interference with the fluoride ions because of similarity in ionic charge and ionic radius. The conclusions obtained from the batch experiments were similar to the results that were obtained with rare earth oxides as adsorbent (Raichur & Basu, 2001).

Table – 6.4 Effect of pH on Defluoridation

Contact Time = 50 Min., Initial Fluoride Concentration (mg/L) = 5.0, Marble Slurry Dose = 15 gm/L

S. No.		1	2	3	4	5	6	7
pH of Aqueous Solution		4.16	5.15	5.87	6.12	7.01	8.3	8.96
Final Concentration of Fluoride (mg/L)		4.01	3.63	3.28	2.80	2.78	2.88	3.36
Fluoride Removal	**mg/L**	0.99	1.37	1.72	2.20	2.22	2.12	1.64
	%	19.8%	27.4%	34.4%	44.0%	44.4%	42.4%	32.8%

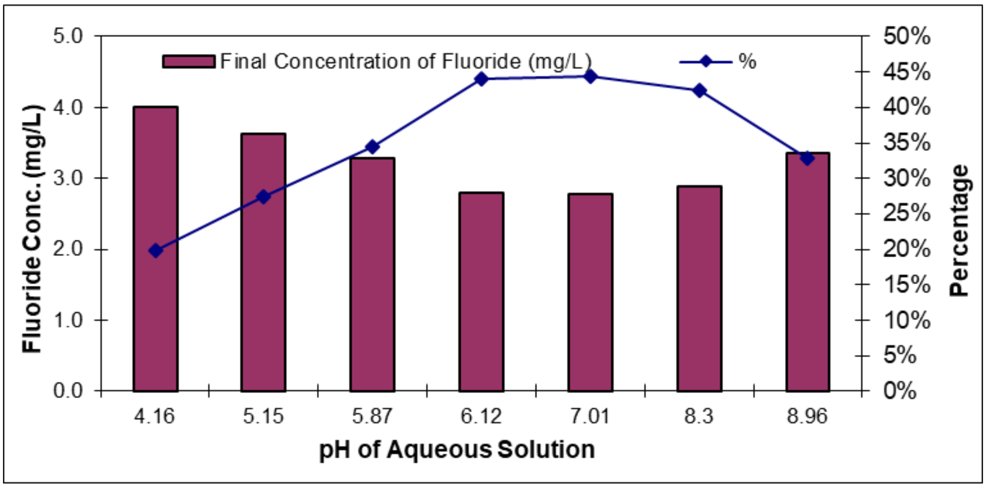


Fig. 6.4 Effect of pH on Defluoridation

6.4.5 Effect of Co-existing Anions

Along with fluoride ions, there were other anions as well which compete for adsorption on the marble slurry. The effect of ions such as sulphate, bicarbonate, phosphate, nitrate and chloride ions was studied. Anion (Cl^-, SO_4^{2-}, HCO_3^-, PO_4^{3-} and NO_3^-) concentrations of 10, 50, 100, 250, 500, 750 and 1000 mg/L were made by dissolving the appropriate amount of required sodium salt in 5 mg/L fluoride solution. It was concluded from the experiments that anions such as Cl^-, SO_4^{2-}, PO_4^{3-} and NO_3^- have insignificant effect on fluoride adsorption whereas HCO_3^- showed declining effect on removal of fluoride ions. Kamble et al., Sujana et al. and Maliyekkal have found out that presence of various other ions in water influence defluorosis efficiency of adsorbent (Sujana et al., 1998; Kamble et al., 2007; Maliyekkal et al., 2008). It was concluded HCO_3^- anion had a declining effect on defluorosis because of the pH variance and the interaction between co existing anions.

6.5 ADSORPTION ISOTHERM

Various adsorption isotherms are used for the design of adsorption system. Freundlich and Langmuir isotherms help in expressing the equilibrium position in the adsorption process when the fluoride ions are distributed between the solid and the liquid phase.

6.5.1 Freundlich Isotherm

Freundlich isotherm, which indicates the heterogeneity of the adsorbent, gave the following linearized equation:

$$log\frac{x}{m} = logK + \frac{1}{n}\log C$$

Where, x = Mass of solute adsorbed (mg)

m = Mass of adsorbent used (g)

C = Solute concentration at equilibrium

K = Constant which is a degree of adsorption capacity

$\frac{1}{n}$ = Degree of adsorption intensity

The values of slope and intercept gave the values of K and n from the plot between $\log\frac{x}{m}$ and $\log C$. Freundlich isotherm deals with physisorption and chemisorption on heterogenous surfaces. Various parameters for plotting of freundlich isotherm are given in Table – 6.5. The value of K (adsorption capacity) was 0.23 mg/g and that of n (adsorption intensity) was 2.38 for marble slurry according to Fig. 6.5. The R^2 value was found to be less than 0.99.

Table – 6.5 Various Parameters for Freundlich & Langmuir Isotherms

S. No.	Adsorbent dose (gm/L)	Initial Fluoride Conc. (mg/L)	pH	Contact Time (min.)	Final Fluoride Conc. (C) (mg/L)	Capacity (mg F/Gm) (x/m)	log C	log (x/m)	1/C	1/x/m
1	15	1.5	7	50	0.16	0.09	-0.7959	-1.0490	6.25	11.19
2	15	2.5	7	50	0.43	0.14	-0.3665	-0.8601	2.33	7.25
3	15	3.5	7	50	0.92	0.17	-0.0362	-0.7645	1.09	5.81
4	15	4.5	7	50	1.62	0.19	0.2095	-0.7167	0.62	5.21
5	15	5.5	7	50	2.25	0.22	0.3522	-0.6642	0.44	4.62
6	15	6.5	7	50	3.69	0.19	0.5670	-0.7274	0.27	5.34
7	15	7.5	7	50	4.51	0.20	0.6542	-0.7004	0.22	5.02

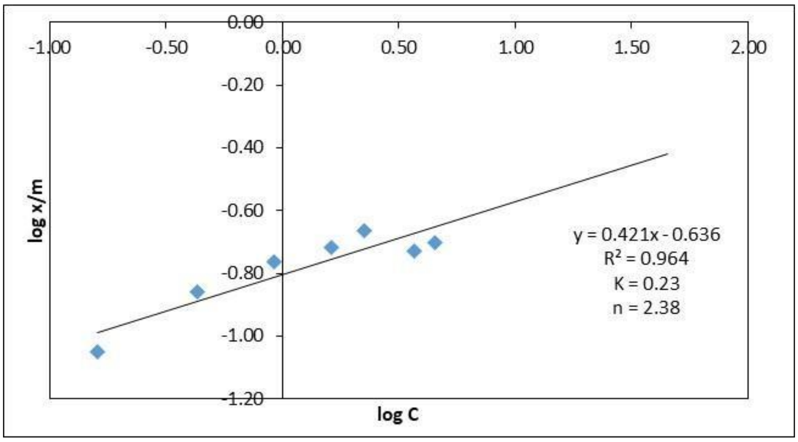


Fig. 6.5 Fluoride adsorption study (Freundlich Isotherm)

6.5.2 Langmuir Isotherm

According to Langmuir, adsorbate forms a single layer on outer surface of adsorbent. This is because residual valencies reside on the surface of adsorbent, which can adsorb only one molecule. In addition, it is presumed that all valencies have equal affinity for adsorbate molecules. The presence of adsorbate on one site doesn't affect the adsorption on adjacent sites. Langmuir gave the following equation:

$$\frac{1}{x/m} = \frac{1}{q} + \frac{1}{q_n b C}$$

Where, x/m = mass of fluoride adsorbed per unit area.

C = solute concentration at equilibrium (mg/L)

q = Langmuir constant representing maximum monolayer formation.

b = Langmuir constant related to energy of adsorption.

Various parameters for plotting of langmuir isotherm are given in Table – 6.5. The Langmuir isotherm plot of $^1/_{\frac{x}{m}}$ vs $^1/_C$ is shown in the Fig. 6.6. As the plot is linear with respect to good correlation coefficients (0.98) which indicates the validity of Langmuir isotherm in the present study.

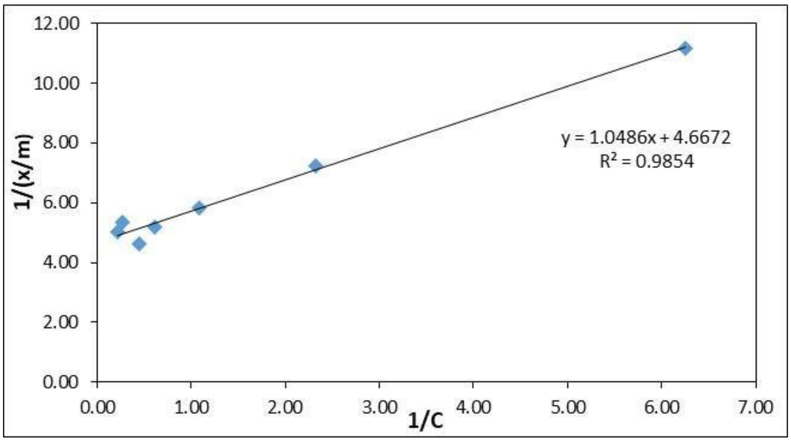


Fig. 6.6 Fluoride adsorption study (Langmuir isotherm)

SUMMARY

The study shows that marble slurry is a cost effective as well as highly effective adsorbent for defluoridation of water. Adsorption of fluoride primarily depends on the pH value, initial fluroride concentration, adsorbent dose, contact time and co-existing anions. The optimum conditions for defluorosis from aqueous solution was obtained to be adsorbent dose of 15 gm/L, contact time of 50 mins, and at the pH range of 6.12 and 7.01. At optimum conditions, fluoride removal efficiency of marble slurry was found upto 89.3% at initial fluoride concentration of 1.5 mg/L. It was found from the study that co-existing anions especially HCO_3 have a declining effect on adsorption of fluoride ions. Langmuir adsorption isotherm gave the better explanation for surface properties of adsorbent.

REFERENCES

1. Abe I., Iwasaki S., Tokimoto T., Kawasaki N., Nakamura T., Tanada S., 2004. Adsorption of fluoride ions onto carbonaceous materials. Journal of Colloid and Interface Science. 275, 35.
2. Adimalla N., Li P., Qian H., 2019. Evaluation of groundwater contamination for fluoride and nitrate in semi-arid region of Nirmal Province, South India: A special emphasis on human health risk assessment (HHRA). Human and Ecological Risk Assessment: An International Journal. 25, 5.
3. Adimalla N., Venkatayogi S., 2016. Mechanism of fluoride enrichment in groundwater of hard rock aquifers in Medak, Telangana State, South India. Environmental Earth Sciences. 76, 45.
4. Agarwal M., Rai K., Shrivastav R., Dass S., 2002. Fluoride Speciation in Aqueous Suspensions of Montmorillonite and Kaolinite, Toxicological & Environmental Chemistry. 82, (1-2) 11-21. DOI: 10.1080/713746660.
5. Agarwal M., Rai K., Shrivastav R., Dass S., 2003. Defluoridation of water using amended clay. Journal of Cleaner Production. 11, 439–444.
6. Ahamad K.U., Mahanta A., Ahmed S. 2019. Removal of Fluoride from Groundwater by Adsorption onto Brick Powder–Alum–Calcium-Infused Adsorbent. Advances in Waste Management. 231-242.
7. Alkan E., Kir E., Oksuz L., 2008. Plasma modification of the anion-exchange membrane and its influence on fluoride removal from water. Separation and Purification Technology. 61, 455–460.
8. Annouar S., Mountadar M., Soufiane A., Elmidaoui A., Menkouchi Sahli M.A., 2004. Defluoridation of underground water by adsorption on the chitosan and by electrodialysis. Desalination. 165, 437.
9. APHA, 2017. Standard Methods for the Examination of Water and Wastewater (23rd Ed, 2017). American Public Health Association. Washington, DC.
10. Apparao B.V., Kartikeyan G., 1986. Permissible limits of fluoride on in drinking water in India in rural environment. Indian Journal of Environmental Protection. 6, 172–175.
11. Arif M., Hussain I., Hussain J., Sharma S., Kumar S., 2012. Fluoride in the Drinking Water of Nagaur Tehsil of Nagaur District, Rajasthan, India. Bulletin of Environmental Contamination and Toxicology. 88, 870–875.

12. Arif M., Hussain J., Husain I., Kumar S., 2013. An Assessment of Fluoride Concentration in Groundwater and Risk on Health of North Part of Nagaur District, Rajasthan, India. World Applied Sciences Journal. 24, (2) 146-153.
13. Arora M., Maheshwari R.C., Jain S.K., Gupta A., 2004. Use of membrane technology for potable water production. Desalination. 170, 105–112.
14. Asimeng B.O., Fiankob J.R., Kaufmann E.E., Tiburua E.K., Hayford C.F., Anani P.A., Dzikunu O.K., 2018. Preparation and characterization of hydroxyapatite from Achatina achatina snail shells: effect of carbonate substitution and trace elements on defluoridation of water. Journal of Asian Ceramic Societies. 6, (3) 205–212.
15. Ayala L.I.M., Paquet M., Janowska K., Jamard P., Quist-Jensen C.A., Bosio G.N., Martire D.O., Fabbri D., Boffa V., 2018. Water Defluoridation: Nanofiltration vs Membrane Distillation. Indian Engineering Chemical Research Journal. 57, (43) 14740-14748.
16. BIS, 2012. Drinking Water Standard 10500, Bureau of Indian Standard, India.
17. Biswas K., Saha S.K., Ghosh U.C., (2007). Adsorption of fluoride from aqueous solution by a synthetic iron(III)–aluminum(III) mixed oxide. Industrial & Engineering Chemistry Research. 46, 5346–5356.
18. Boubakri A., Helali N., Tlili M., Amor M.B., 2014. Fluoride removal from diluted solutions by Donnan dialysis using full factorial design. Korean Journal of Chemical Engineering. 31, (3) 461-466.
19. Bulusu K.R., Nawlakhe W.G., 1988. Defluoridation of water with activated alumina: batch operations. Indian Journal of Environmental Health. 30, 262–299.
20. Castel C., Schweizer M., Simonnot M.O., Sardin M., 2000. Selective removal of fluoride ions by a two-way ion-exchange cyclic process. Chemical Engineering Science. 55, 3341–3352.
21. Cengeloglu Y., Kir E., Ersoz M., 2002. Removal of fluoride from aqueous solution by using red mud. Separation and Purification Technology. 28, 81–6.
22. Chubar N.I., Samanidou V.F., Kouts V.S., Gallios G.G., Kanibolotsky V.A., Strelko V.V., Zhuravlev I.Z., 2005. Adsorption of fluoride, chloride, bromide, and bromate ions on a novel ion exchanger. Journal of Colloid and Interface Science. 291, 67-74.

23. Das N., Pattanaik P., Das R., 2005. Defluoridation of drinking water using activated titanium rich bauxite. Journal of Colloid and Interface Science. 292, (1) 1-10.
24. Dehghani M.H., Haghighat G.A., Yetilmezsoy K., McKay G., Heibati B., Tyagi I., Agarwal S., Gupta V.K., 2016. Adsorptive removal of fluoride from aqueous solution using single- and multi-walled carbon nanotubes. Journal of Molecular Liquids. 216, 401-410.
25. Durmaz F., Kara H., Cengeloglu Y., Ersoz M., 2005. Fluoride removal by donnan dialysis with anion exchange membranes, Desalination, 177, (1-3) 51-57.
26. Fan X., Parker D.J., Smith M.D., 2003. Adsorption kinetics of fluoride on low cost materials, Water Research. 37, 4929–4937.
27. Ghorai S., Pant K.K., 2005. Equilibrium, kinetics and breakthrough studies for adsorption of fluoride on activated alumina. Separation and Purification Technology. 42, 265–271.
28. Grames H., Persin F., Sandeaux J., Pourcelly G., Mountadar M., 2002. Defluoridation of groundwater by a hybrid process combining adsorption and Donnan dialysis. Desalination. 145, 287-291.
29. Haron M.J., Wan Yunus W.M.Z., Wasay S.A., 1995. Sorption of natural fluoride, US Environmental Protection Agency, of fluoride ions from aqueous solutions by a yttrium-loaded poly (hydroxamic acid) resin. International Journal of Environment. 48, 245–255.
30. Hichour M., Persin F., Sandeaux J., Gavach C., 1999. Fluoride removal from waters by Donnan dialysis. Separation and Purification Technology. 18, (1-3) 1-11.
31. Ho L.N., Ishihara T., Ueshima S., Nishiguchi H., Takita Y., 2004. Removal of fluoride from water through ion exchange by mesoporous Ti oxohydroxide. Journal of Colloid and Interface Science. 272, 399–403.
32. Husain I., Arif M., Husain J., 2012. Fluoride contamination in drinking water in rural habitations of central Rajasthan, India. Environmental Monitoring and Assessment. 184, (8) 5151–5158.
33. Husain J., Husain I., Arif M., 2013. Fluoride contamination in groundwater of central Rajasthan, India and its toxicity in rural habitants, Toxicological & Environmental Chemistry, http://dx.doi.org/10.1080/02772248.2013.832545
34. Husain J., Husain I., Sharma K.C., 2010. Fluoride and health hazards:

community perception in a fluorotic area of Central Rajasthan (India), an arid environment. Environmental Monitoring and Assessment. 162, 1–14.

35. Hussain I., Hussain J., Sharma K.C., Ojha K.G., 2002. Fluoride in Drinking Water and Health Hazardous: Some Observations on Fluoride Distribution Rajasthan. In Environmental Scenario of 21st Century, 355–374. New Delhi: APH.
36. Hussain J., Sharma K.C., Hussain I., 2004. Fluoride in drinking water and its ill affect on human health: a review. Journal of Tissue Research. 4, (2) 263–273.
37. Kamble S.P., Jagtap S., Labhsetwar N.K., Thakare D., Godfrey S., Devotta S., Rayalu S.S., 2007. Defluoridation of drinking water using chitin, chitosan and lanthanum-modified chitosan. Chemical Engineering Journal. 129, 173-180.
38. Karthikeyan G., Apparao B.V., Meenakshi S., 1997. Defluoridation Properties of Activated Alumina", In: Proceedings of the 2nd International Workshop on Fluorosis Prevention and Defluoridation of Water, Nazreth, Ethiopia, 1997, pp. 78–82. [online] Available at: http://www.de-fluoride.net/2ndproceedings/78-82.pdf [Accessed: 31 January 2018]
39. Bhargava D.S., Killedar D.J., 1995. Relationship in fluoride adsorption on fishbone charcoal. Indian Journal of Engineering & Materials Sciences. 2, 157-162.
40. Lai Y.D., Liu J.C., 1996. Fluoride removal from water with spent catalyst. Separation Science and Technology. 31, 2791–2803.
41. Lee D.R., Hargreaves J.M., Badertocher L., Rein L., Kassir F., 1995. Reverse osmosis and activated alumina water treatment plant for the California State prisons located near Blythe. Desalination 103, 155–161.
42. Leyva-Ramos R., Medellin-Castillo N.A., Jacobo-Azuara A., Mendoza-Barron J., Landin-Rodriguez L.E., Martínez-Rosales J.M., Aragon-Piña A., 2008. Fluoride removal from water solution by adsorption on activated alumina prepared from pseudo-boehmite. Journal of Environmental and Management, 18, (5) 301–309.
43. Li Y.H., Wang S., Cao A., Zhao D., Zhang X., Xu C., Luan Z., Ruan D., Liang J., Wu D., Wei B., 2001. Adsorption of fluoride from water by amorphous alumina supported on carbon nanotubes. Chemical Physics Letters. 50, 412–416.
44. Lounici H., Adour L., Belhocine D., Elmidaoui A., Bariou B., Mameri N., 2001. Novel technique to regenerate activated alumina bed saturated by fluoride ions.

Journal of Chemical Engineering. 81, 153–160.

45. Lv_L., Heb J., Weib M., Evansb D.G., Zhoua Z., 2007. Treatment of high fluoride concentration water by MgAl-CO3 layered double hydroxides: Kinetic and equilibrium studies. Water Research. 41, 1534 – 1542.
46. Mahmoudi M.M., Nasseri S., Mahvi A.H., Dargahi A., Khubestani M.S., Salari M., 2019. Fluoride removal from aqueous solution by acid-treated clinoptilolite: Isotherm and kinetic. Desalination and Water Treatment. 146, 333-340.
47. Mahramanlioglu M., Kizilcikli I., Bicer I.O., 2002. Adsorption of fluoride from aqueous solution by acid treated spent bleaching earth. Journal of Fluorine Chemistry. 115, 41–47.
48. Maliyekkal S.M., Sharma A.K., Philip L., 2006. Manganese-oxide-coated alumina: A promising sorbent for defluoridation of water. Water Research. 40, (19) 3497-3506.
49. Maliyekkal S.M., Shukla S., Philip L., Nambi I.M., 2008. Enhanced fluoride removal from drinking water by magnesia-amended activated alumina granules, Chemical Engineering Journal. 140, 183–192.
50. Mameri N., Yeddou A.R., Lounici H., Belhocine D., Grib H., Bariou B., 1998. Defluoridation of septentrional Sahara water of North Africa by electrocoagulation process using bipolar aluminium electrodes. Water Research. 32, 1604–1612.
51. Mohan D., Sharma R., Singh V.K., Steele P., Jr. Pittman C.U., 2012. Fluoride Removal from Water using Bio-Char, a Green Waste, Low-Cost Adsorbent: Equilibrium Uptake and Sorption Dynamics Modeling. Industrial & Engineering Chemistry Research. 51, 900-914.
52. Mohapatra D., Mishra D., Mishra S.P., Roy Chaudhury G., Das R.P., 2004. Use of oxide minerals to abate fluoride from water. Journal of Colloid and Interface Science. 275, 355–359.
53. Mohapatra M., Anand S., Mishra B.K., Giles D.E., Singh P., 2009. Review of fluoride removal from drinking water. Journal of Environmental Management. 91, 67-77.
54. Naoki H., Masahiro M., Hajime O., Akindou S., Takeji E., Tooru K., 1996. Measurement of fluoride ion in the river-water flowing into Lake Biwa. Water Research. 30, (4) 865–868.

55. Narsimha A., Sudarshan V., 2017. Assessment of fluoride contamination in groundwater from Basara, Adilabad District, Telangana State, India. Applied Water Science. 7, 2717–2725
56. Nawlakhe W.G., Kulkarni D.N., Pathak B.N., Bulusu K.R., 1975. De-fluoridation of Water by Nalgonda Technique. Indian Journal of Environmental Health. 17, 26.
57. Parthasarathy N., Buffl J., Haerdi W., 1986. Combined use of calcium salts and polymeric aluminum hydroxide for defluoridation of waste waters. Water Research. 20, 443–448.
58. Podgorski J.E., Labhasetwar P., Saha D., Berg M., 2018. Prediction Modeling and Mapping of Groundwater Fluoride Contamination throughout India. Environmental Science & Technology. 52, (17) 9889-9898.
59. Qureshi S.Z., Khan M.A., Rahman N., 1995. Removal of fluoride ion by zirconium (IV) arsenate vanadate using ion selective electrode. Water Treatment. 10, 307–312.
60. Raichur A.M., Basu M.J., 2001. Adsorption of fluoride onto mixed rare earth oxides. Separation and Purification Technology. 24, 121–127.
61. Raj D., Shaji E., 2017. Fluoride contamination in groundwater resources of Alleppey, southern India. Geoscience Frontiers. 8, (1) 117-124.
62. Rajput A., Raj S.K., Sharma P.P., Yadav V., Sarvaia H., Gupta H., Kulshrestha V., 2018. Synthesis and characterization of aluminium modified graphene oxide: an approach towards defluoridation of potable water. Journal of Dispersion Science And Technology. 1-9, https://doi.org/10.1080/01932691.2018.1496836
63. Ramos R.L., Ovalle-Turrubiartes J., Sanchez-Castillo M.A., 1999. Adsorption of fluoride from aqueous solution on aluminum-impregnated carbon. Carbon. 37, 609–617.
64. Reardon E.J., Wang Y., 2001. Activation and regeneration of a soil sorbent for defluoridation of drinking water. Applied Geochemistry. 16, 531–539.
65. Saha S., 1993. Treatment of aqueous effluent for fluoride removal. Water Research. 27, 1347–1350.
66. Saikia J., Sarmah S., Ahmed T.H., Kalita P.J., Goswamee R.L., 2017. Removal of toxic fluoride ion from water using low cost ceramic nodules prepared from some locally available raw materials of Assam, India. Journal of Environmental Chemical Engineering. 5, (3) 2488-2497.

67. Schneiter R.W., Middlebrooks E.J., 1983. Arsenic and fluoride removal from groundwater by reverse osmosis. Environment International. 9, 289–291.
68. Shen J., Richards B.S., Schafer A.I., 2016. Renewable energy powered membrane technology: Case study of St. Dorcas borehole in Tanzania demonstrating fluoride removal via nanofiltration/reverse osmosis. Seperation and Purification Technology. 170, 445-452.
69. Singh P.K., Saharan V.K., George S., 2018. Studies on performance characteristics of calcium and magnesium amended alumina for defluoridation of drinking water. Journal of Environmental Chemical Engineering, 6 (1) 1364-1377.
70. Sneha J., Yenkie M.K., Labhsetwar N., Rayalu S., 2012. Fluoride in drinking water and defluoridation of water. Chemical Reviews. 112, 2454–2466. doi.org/10.1021/cr2002855.
71. Sorg T.J., 1978. Treatment technology to meet the interim primary drinking water regulations for inorganics. Journal of the American Water Works Association. 70, (2) 105–111.
72. Srimurali M., Pragathi A., Karthikeyan J., 1998. A study on removal of fluorides from drinking water by adsorption onto low-cost materials. Environmental Pollution. 99, 285–289.
73. Stewart, T. 2009."Removal of Fluoride from Drinking Water: Analysis of Alumina based Sorption", Term Paper, FS, Institute of Biogeochemistry and Pollutant Dynamics, Department Environmental Science, ETH, Zürich, 3, pp. 22–24.
74. Sujana M.G., Thakur R.S., Rao S.B., 1998**.** Removal of fluoride from aqueous solution by using alum sludge. Journal of Colloid and Interface Science. 206, 94–101.
75. Tahaikt M., Achary I., Menkouchi Sahli M.A., Amor Z., Taky M., Alami A., Boughriba A., Hafsi M., Elmidaoui A., 2006. Defluoridation of Moroccan groundwater by electrodialysis: continuous operation. Desalination. 189, (1-3) 215-220.
76. Tang Y., Guan X., Su T., Gao N., Wang J., 2008. Fluoride adsorption onto activated alumina: Modeling the effects of pH and some competing ions. Colloids and Surfaces A: Physicochemical and Engineering Aspects. doi:10.1016/j.colsurfa.2008.11.027

77. Tor A., 2006. Removal of fluoride from an aqueous solution by using montmorillonite Desalination. 201, 267–276.
78. Tripathy S.S., Raichur A.M., 2008. Abatement of fluoride from water using manganese dioxide-coated activated alumina. Journal of Hazardous Materials. 153, (3) 1043-1051.
79. Tripathy S.S., Srivastava S.B., Bersillon J.L., Gopal K., 2004. Removal of fluoride from drinking water by using low cost adsorbents, in: Proceedings of the 9th FECS Conference and 2nd SFC Meeting on Chemistry and the Environment, Bordeaux, France, 352.
80. Tsutsui T., Suzuki N., Ohmori M., Maizumi H., 1984. Cytotoxicity, chromosome aberrations and unscheduled DNA synthesis in cultured human diploid fibroblasts induced by sodium fluoride. Mutation Research. 139, (4) 193–198.
81. UNICEF, 1999. States of the art report on the extent of fluoride in drinking water and the resulting endemicity in India. Report by fluorosis and rural development foundation for UNICEF, New Delhi.
82. US Public Health Service Drinking Water Standards, 1962. Department of Health Education and Welfare, Washington, DC.
83. Wang A.G., Xia T., Chu Q.L., Zhang M., Liu F., Chen X.M., Yang K.D., 2004. Effects of fluoride on lipid peroxidation, DNA damage and apoptosis in human embryo hepatocytes. Biomedical and Environmental Sciences. 17, (2) 217–222.
84. WHO, 2006. Guidelines for drinking-water quality first addendum to third edition. Volume1 Recommendations.

(www. who.int/water_sanitation_health/dwq/gdwq0506.pdfS)

85. Wong E.Y., Stenstrom M.K., 2017. Onsite defluoridation system for drinking water treatment using calcium carbonate. Journal of Environmental Management. 1-5. http://dx.doi.org/10.1016/j.jenvman.2017.06.060
86. Xia Y., Huang X., Li W., Zhang Y., Li Z., 2019. Facile defluoridation of drinking water by forming shell@fluorapatite nanoarray during boiling egg shell. Journal of Hazardous Materials. 361, 321–328.
87. Yami T.L., Chamberlain J.F., Beshah F.Z., Sabatini D.A., 2018. Performance enhancement of Nalgonda technique and pilot testing electrolytic defluoridation system for removing fluoride from drinking water in East Africa. African Journal of Environmental Science & Technology. 12, (10) 357-369.

88. Zevenbergen C., Van Reeuwijk L.P., Frapporti G., Louws R.J., Schuiling R.D., 1996. A simple method for defluoridation of drinking water at village level by adsorption on Ando soil in Kenya. Science of the Total Environment. 188, 225–232.

89. Zhang Q., Liang H., 1992. Aluminium phosphate for the defluorination of potable water. Environment International. 18, 307–310.

Chapter 7

SUMMARY & CONCLUSION

SUMMARY

The present investigation entitled “Impact of Agricultural, Industrial and Domestic waste on Groundwater quality of Gautam Budh Nagar district, Uttar Pradesh, India” was carried out in the selected villages of district. Study was conducted for quantitative analysis of physico-chemical parameters and heavy metals in groundwater samples and waste water samples of the villages. Water samples were collected from eleven villages of district GBN; Duryai, Talabpur, Khera Dharampura, Bishnuli, Achheja, Dujana, Badalpur, Sadopur, Dairy Maccha, Dhoom Manikpur and Badhpura. To assess the effects of waste water on groundwater quality, study area was divided into three zones; Agricultural zone, Industrial zone & Residential zone. Twenty two water quality stations were set up for groundwater sampling. On the basis of survey and field study, thirteen sites were identified for waste water sampling. From each site groundwater and waste water samples were collected in pre-monsoon season (in the month of June) and post-monsoon season (in the month of October) for three consecutive years - 2016, 2017, 2018.

Physico-chemical parameters such as pH, electrical conductivity, total dissolved solids, turbidity, total hardness, calcium, magnesium, sodium, potassium, boron, total alkalinity, chloride, fluoride, nitrite, nitrate, phosphate, sulphate and ammonia were analysed in groundwater samples in the National River Quality laboratory at Central Water Commission, Delhi. Quantitative analysis of various heavy metals (Arsenic, cadmium, chromium, copper, Nickel, Lead, Iron & Zinc) was done using atomic absorption spectroscopy. From the results of physico-chemical analysis, water quality index (WAWQI, GWQI & CCME WQI) and suitability of ground water for irrigation and drinking purposes were determined. To know the effects of waste water on groundwater quality, characterization of waste water originated from agricultural area, industrial area and residential area was also done. Information about the health status of inhabitant of study area was also collected using survey method. A novel approach to remove fluoride ions from aqueous solution using marble slurry was also done through batch experiments. The results of study revealed that characteristics of waste water affects the quality of groundwater.

HEALTH STATUS

- The health survey revealed that inhabitants of villages were suffering from various health disorders
- Major health issue in the study area was carcinogenicity, but it was also noticed that gastro-intestinal problems were common among inhabitants at all the sites.
- The survey revealed that maximum inhabitants blamed polluted water to be responsible for health related issues.

GROUNDWATER QUALITY

In agricultural zone of study area, groundwater have higher concentration of boron, nitrate & phosphate. Ionic concentration in groundwater decreased in post-monsoon season however chloride strength increased after rain fall. Among the analysed heavy metals, iron concentration was found high in groundwater samples of agricultural zone. The extensive use of fertilizers for better crop yield was responsible for elevated content of boron, nitrate, phosphate, chloride and iron. Water quality index of samples showed that groundwater quality at Duryai station was unfit for drinking. On the basis of irrigational parameters, groundwater quality of agricultural area was safe for irrigation. Analysed agricultural waste water samples had high content of ammonia, potassium, nitrate and iron. These analytical results reflect that groundwater quality of agricultural prone areas was affected by agricultural runoff.

In industrial zone of study area, groundwater was hard and heavily contaminated. High ionic concentration of calcium, sodium, potassium, fluoride, chloride and sulphate was obtained in samples collected from industrial area. Metal content of samples of industrial area was very high. Mean values of arsenic, chromium, copper, nickel, lead and zinc were maximum in groundwater samples of industrial zone. On the basis of WQI, groundwater of Bisrakh Road and Achheja water quality stations was not fit for drinking purpose. Groundwater of industrial area was highly saline hence unsuitable for irrigation. Waste water samples of industrial areas have excessive ionic concentration and high content of analysed metals (As, Cr, Cu, Pb, Ni, Fe & Zn). The specific occurrence of metal ions in waste water samples clearly indicates the effect of effluent of nearby industry.

Groundwater of residential zone was highly alkaline and have high concentration of magnesium, fluoride, nitrite and ammonia. High cadmium content was obtained from the groundwater samples of Dhoom Manikpur. Effluent of cement factory, present in Dhoom Manikpur adversely affected groundwater quality. Water quality index data revealed that all the stations in residential zone (Sadopur, Dhoom Manikpur, Dairy Maccha & Badhpura) have groundwater quality unfit for drinking. Irrigational water quality of residential zone was comparatively poor than industrial and agricultural zone. Domestic waste water samples were very turbid with high alkalinity. Mean value of magnesium, fluoride, nitrite, phosphate and cadmium were maximum in domestic waste water samples.

DEFLUORIDATION OF AQUEOUS SOLUTION

In present study, marble slurry is proved as an efficient adsorbent for the removal of excess of fluoride from aqueous solution. Under optimum conditions, its fluoride removal efficiency was obtained upto 89.3%. As marble slurry is produced as a by-product from marble industry, its use in defluoridation is cost effective. Marble slurry also has some ecological threats so its reuse protects the environment.

CONCLUSION

The results of study revealed that groundwater of district Gautam Budh Nagar was loaded with high ionic content as well as heavy metals. The waste water samples contained high value of pH, electrical conductivity, total hardness, total dissolved solids, cations, anions, and heavy metals in both seasons. Characteristics of waste water greatly affected groundwater quality. Leaching of hazardous chemicals present in effluents of steel-iron industry, rice mill, paper industry, fabric dyeing industry added a significant amount of pollutants in ground aquifers. Results of physico-chemical analysis, metal analysis and water quality index revealed that groundwater of agricultural zone was suitable for drinking and irrigation. Groundwater of industrial zone was highly polluted and level of pollutants depend upon the type of industry present in the region. Groundwater quality of residential zone was unfit for human consumption and irrigation. Appropriate measures need to be taken immediately otherwise contamination can reach to ground aquifers of other regions. Results of seasonal variation in quality parameters showed that recharging of ground aquifers in monsoon season, lessened the contamination upto a great extent.

RECOMMENDATIONS

- On the basis of current study, regular water quality monitoring, water quality management and restoration programs should be conducted in study area.
- In agricultural prone areas, reckless use of fertilizers should be discouraged.
- Farmers should be encouraged to take the benefits of soil health card scheme promoted by Ministry of Agriculture and Farmers Welfare.
- Treatment of waste water, generated in industries, is required before dumping it.
- Development of appropriate sanitation facilities is required in residential area.
- Segregation of waste at the source level so as to ensure that the reusable/ recyclable and metal oriented waste is not dumped.
- Treatment of groundwater is requisite before it is supplied to the water distribution system.
- The study concluded that awareness campaigns about the deteriorating quality of water should be conducted by the government through various conventional means and social media.
- In problematic areas, effective management and remedial measures for groundwater quality should be applied.
- Policies will be prepared on state and national level to avoid further deterioration of groundwater quality.

SCOPE FOR FUTURE WORKS

- Model can be developed on the basis of relation between the geographical profile of the study area and groundwater contamination.
- Study can be extended for microbial quality of water.
- Further in the problem zones, pollution sources can be monitored and new treatment techniques can be developed.
- Studies can be conducted regarding the possibilities of waterborne disease in the area.

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Oct. 2017
Name of Village- Talabpur

1. Information on Respondent

Name	Ashok
Age	Under 18 Between 18 & 30 31 yrs Above 30
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student [✓ Employee] Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years [✓ 10 years] More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	[✓ Yes] No Not sure
If No, rate the quality of water.	Bad Poor Very Poor
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	[✓ From Handpumps] From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes Industrial wastes
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required (✓) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	—
When do you know (year).	
Do you consider effluent of industries as a problem.	Yes No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes No

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Oct. 2017
Name of Village- Durgai

1. Information on Respondent

Name	Kiranpal
Age	Under 18 Between 18 & 30 32 yrs Above 30
Sex	[✓ Male] Female
Education	10th ( ) 12th (✓) Graduate ( ) Post-graduate ( )
Occupation	Student [✓ Employee] Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	[✓ Yes] No Not sure
If No, rate the quality of water.	Bad Poor Very Poor
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	[✓ From Handpumps] From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes Industrial wastes
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required (✓) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	—
When do you know (year).	
Do you consider effluent of industries as a problem.	Yes No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes No

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Dujana.

1. Information on Respondent

Name	RanPal Nagar (Pradhan)
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th (✓) Graduate ( ) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( ) Bore Well
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( ) Bore Well
From how many years are you using that source of water.	5 years [✓ 10 years] More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L 3.0 L [✓ 3.5L] More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Poor Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO (✓) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes [✓ Nearby drainage] Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Gastro - Intestinal
When do you know (year).	2003
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	2010
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Oujana

1. Information on Respondent

Name	Sushma
Age	[✓ Under 18] Between 18 & 30 Above 30
Sex	Male [✓ Female]
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	[✓ Student] Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	[✓ 5 years] 10 years More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L 3.0 L [✓ 3.5L] More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad [✓ Poor] Very Poor
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF (✓) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes [✓ Nearby drainage] Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Sometimes throat infection
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Dujana

1. Information on Respondent

Name	Ajit Nagar
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student Employee [✓ Business] Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Heart problem
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Dujana

1. Information on Respondent

Name	Indra Nagar
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student Employee [✓ Business] Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad [✓ Poor] Very Poor
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home. .	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF (✓) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Stomach-ache / Throat
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Dujana

1. Information on Respondent

Name	Ramu
Age	Under 18 Between 18 & 30 Above 30 80 Years
Sex	[✓ Male] Female
Education	Illiterate 10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L [✓ 1.5 L] 2.0 L 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	[✓ Yes] No Not sure
If No, rate the quality of water.	Bad Poor Very Poor
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	[✓ From Handpumps] From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required (✓) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem. ✓	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 [✓ Between 18 & 30] Above 30
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Dujana

1. Information on Respondent

Name	SANJU NAGAR
Age	Under 18 [✓ Between 18 & 30] Above 30
Sex	Male [✓ Female]
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	[✓ Student] Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years [✓ 10 years] More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Badhpura

1. Information on Respondent

Name	Vinay Rawal
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Hand-Pump (✓) Bottled water ( )	Govt. TW ( ) Public water supply ( )
What is the source of Cooking water.	Pvt. TW ( ) Hand-Pump (✓) Bottled water ( )	Govt. TW ( ) Public water supply ( )
From how many years are you using that source of water.	5 years [✓ 10 years] More than 10 years	
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L	
Are you satisfied with the quality of water.	Yes [✓ No] Not sure	
If No, rate the quality of water.	[✓ Poor] Good	Fair Excellent
Generally, how is the smell of your water.	No smell	[✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO (✓) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river [✓ Open fields]

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Cancer liver
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	3 to 4 years
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Badhpura

1. Information on Respondent

Name Kamlesh	
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	Male [✓ Female]
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Farming [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	[✓ 5 years] 10 years More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO (✓) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river [✓ Open fields]

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes]	No
What is the problem.	Breast cancer	
When do you know (year).	5yrs earlier	
Do you consider effluent of industries as a problem.	[✓ Yes]	No
Is there any cancer patient in your family/village.	[✓ Yes]	No
When it was detected (Year).	–	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]	
Is there any medical treatment given/ provided to the patient.	[✓ Yes]	No
Has any action been taken by government/local bodies/ NGO.	Yes	[✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Sadopur

1. Information on Respondent

Name	Mani Ram
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education 8th ✓	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue (✓)

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Cancer (liver)
When do you know (year).	3 Years back
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes Myself No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Accheja.

1. Information on Respondent

Name	Virendra Nagar (Brother of Pradhan)
Age	Under 18 [✓ Between 18 & 30] Above 30
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( ) Borewell
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( ) Borewell
From how many years are you using that source of water.	5 years [✓ 10 years] More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Poor Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO (✓) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river [✓ Open fields]

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Gastro-intestinal
When do you know (year).	From - 5- yeares
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	4-5 years back
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Accheja

1. Information on Respondent

Name	Praveen
Age	Under 18 [✓ Between 18 & 30] Above 30
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( ) Bore well
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water ( ) Borewell
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L 3.0 L [✓ 3.5L] More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO ( ) Kent RO+UV+UF+TDS control (✓)
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes [✓ Nearby drainage] Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes]	No
What is the problem.	Cancer	
When do you know (year).	—	
Do you consider effluent of industries as a problem.	[✓ Yes]	No
Is there any cancer patient in your family/village.	[✓ Yes]	No
When it was detected (Year).	10 years back	
Age of patient.	[✓ Under 18] Between 18 & 30 Above 30	
Is there any medical treatment given/ provided to the patient.	[✓ Yes]	No
Has any action been taken by government/local bodies/ NGO.	Yes	[✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Dhummani Kpur .

1. Information on Respondent

Name G. N. Singh Rawat	
Age 90 yrs .	Under 18 Between 18 & 30 Above 30
Sex Mal .	Male Female
Education M.A. LL.B. Ex Indian Army.	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation Retired from Army .	Student Employee Business Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water. Gl	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water (✓)
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water (✓)
From how many years are you using that source of water.	5 years 10 years More than 10 years More than 30 years .
How much of water do you drink per day.	0.5 L 1.0 L ✓ 1.5 L 2.0 L 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes ✓ No Not sure
If No, rate the quality of water.	Poor Fair Good ✓ Excellent
Generally, how is the smell of your water.	No smell ✓ Foul smell

Generally, how is the taste of your water.	Tasteless Bad taste Tasted
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	[✓ From Handpumps] From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	[✓ Domestic wastes] Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO ( ) Kent RO+UV+UF+TDS control ( ) Noobwee
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage In Ponds. Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	Nothing
When do you know (year).	by birth
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No No Need
Has any action been taken by government/local bodies/ NGO.	Yes No

Note— No action taken by the Govt. and their bodies.

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Badalpur

1. Information on Respondent Jitendra

Name	Jitendra
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th (✓) Graduate ( ) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO (✓) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem. ✓	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] Mother No
When it was detected (Year).	18 months back
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 14/04/2018
Name of Village- Badalpur

1. Information on Respondent

Name	Sanju
Age	[✓ Under 18] Between 18 & 30 Above 30
Sex	Male [✓ Female]
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	[✓ Student] Employee Business Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years [✓ 10 years] More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L 3.0 L [✓ 3.5L] More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO (✓) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Gastro-intestinal problems
When do you know (year).	2-3 Years
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	Don't know
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Badalpur

1. Information on Respondent

Name	Sanjay Singh
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th (✓) Graduate ( ) Post-graduate ( )
Occupation	Student Employee [✓ Business] Farming Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes No [✓ Not sure]
If No, rate the quality of water.	Poor Fair [✓ Good] Excellent
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO (✓) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	[✓ A piped sewer system] [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	2 Years back
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 16th March 2018
Name of Village- Badalpur

1. Information on Respondent

Name	Shri Chand
Age	Under 18 Between 18 & 30 Above 30 60 Years
Sex	[✓ Male] Female
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business [✓ Farming] Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water (✓)
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water (✓)
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	[✓ Yes] No Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue (✓)

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river [✓ Open fields]

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Typhoid
When do you know (year).	2013
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes No
When it was detected (Year).	Don't Know
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes No

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Badalpur

1. Information on Respondent

Name	Rajpati
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	Male [✓ Female]
Education	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Farming [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L [✓ 1.5 L] 2.0 L 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO (✓) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Hip bone cancer
When do you know (year).	From 18 months
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes Herself No
When it was detected (Year).	2016
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Munu Agarwal
Date of Survey- 16th March 2018
Name of Village- Badalpura

1. Information on Respondent

Name	Rekha
Age	Under 18 [✓ Between 18 & 30] Above 30
Sex	Male [✓ Female]
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Farming [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water (✓)
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump ( ) Public water supply ( ) Bottled water (✓)
From how many years are you using that source of water.	[✓ 5 years] 10 years More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Poor] Fair Good Excellent
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	[✓ Yes] No Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue (✓)

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Typhoid.
When do you know (year).	2 yrs, still suffering
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	last year
Age of patient.	Under 18 [✓ Between 18 & 30] Above 30
Is there any medical treatment given/ provided to the patient.	Yes [✓ No]
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Badalpur

1. Information on Respondent

Name Sunita	
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	Male [✓ Female]
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Farming [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	[✓ Yes] No Not sure
If No, rate the quality of water.	Poor Fair Good Excellent
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) Aquaguard RO (✓) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	[✓ A piped sewer system] [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem. ✓	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes No
When it was detected (Year).	Around 4 - 5 Years
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 19/04/2018
Name of Village- Badalpur

1. Information on Respondent

Name	Pinky
Age	Under 18 [✓ Between 18 & 30] Above 30
Sex	Male [✓ Female]
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Farming [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	[✓ 5 years] 10 years More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	[✓ Yes] No Not sure
If No, rate the quality of water.	Poor [✓ Fair] Good Excellent
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	[✓ From Handpumps] From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes Industrial wastes
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) Aquaguard RO ( ) Kent RO ( ) Kent RO+UV+UF+TDS control ( )
If no, what is reason for it.	Not required (✓) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	[✓ Dung cakes] Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	Yes [✓ No]
What is the problem.	
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes Don't know No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Nov. 2019
Name of Village- Sadopur

1. Information on Respondent

Name	Anil Baisoya
Age	Under 18 [✓ Between 18 & 30] Above 30
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	[✓ Student] Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	[✓ 5 years] 10 years More than 10 years
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad [✓ Poor] Very Poor
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	[✓ Yes] No Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	[✓ Domestic wastes] Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Acute bronchitis & acute cervical spasm
When do you know (year).	From last year
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	—
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

DR. ASHOK K. AGGARWAL
M.B.B.S., D.M.R.D.
Regd. No. 23862
CONSULTANT RADIOLOGIST
Member : IRIA, ICRI, IMA, IAMS

(Sonography • Chanda Sona Diagnostics)
87, AMBEDKAR ROAD, GHAZIABAD - 201 001
Phone : 2797120

12 - 08 - 2019.

U. S. SCAN: REPORT.

PT'S NAME :- Mr. Anil ; 25 Yrs./Male.

ADV BY : Self.

Clinical Remarks:-A FUC of post operated (pyeloplasty.) (L) kidney for PUJ obstruction at Yashoda Hospital, GZB. Nov-2018. c/o Dysuria & pain (L) lumbar region.

U. S. SCAN: WHOLE ABDOMEN.

- **LIVER**:-Liver parenchyma shows normal echopattern, no focal mass seen. No calcification changes seen, biliary canaliculi are not dilated. Portal vein caliber-normal.
- **GALL BLADDER**:- measures-51mm x 18mm, wall thickness normal. No cholelithiasis seen.
- **C.B.D.**:- Normal in calibre.

- **BOTH KIDNEYS:-**
- (R)KIDNEY:- Renal Length-119mm. Size, shape, position and outlining-normal. Renal Parenchymal thickness-normal. No calculus seen. Central echo complex seen is normal. No obstructive uropathy changes seen.

- **(L)KIDNEY:- Renal Length-130mm. enlarged shows hydronephrosis changes, renal pelvis is dilated. No calculus seen.**
- **PANCREAS:**- Seen is normal in size and shows normal echopattern.
- **SPLEEN:**- Size, echotexture and outlining-normal.
- Aorta, IVC, seen is normal in caliber. No Ascitis seen.
- No enlarged Para-aortic lymph nodes seen.
- **URINARY BLADDER**: Anaechoic.
  - : Wall thickness-normal.
  - : No calculus seen.
  - : No mass lesion seen.
  - : PRE-VOIDING VOLUME: 151ml.
  - : POST-VOIDING RESIDUE: 31ml.

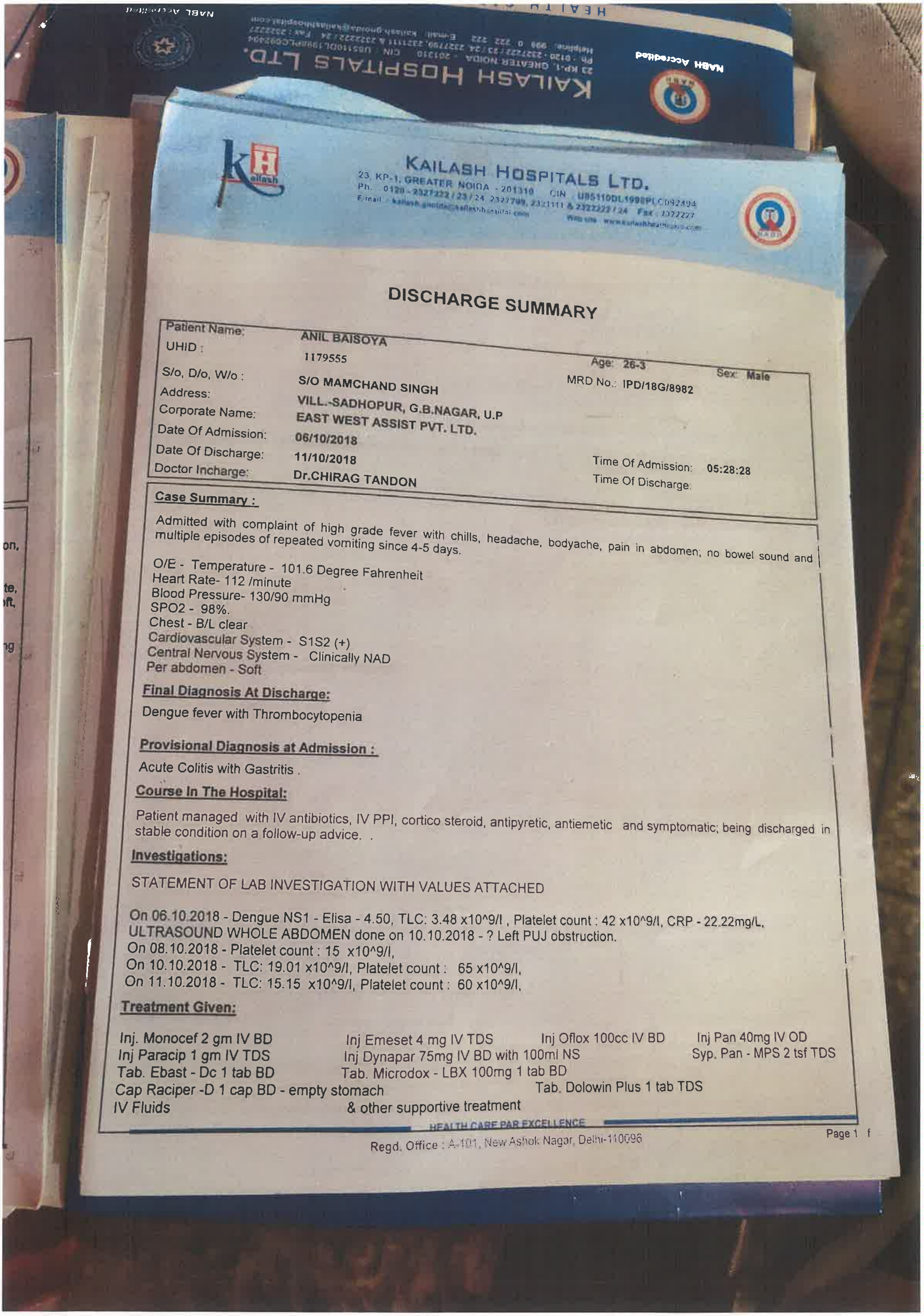
- **PROSTATE**:- size, echotexture and outlining-normal.

ADV- Uro-Surgeon consultation.

DR.ASHOK AGGARWAL.
MBBS.DMRD.
Senior Radiologist





KAILASH HOSPITALS LTD.
23, KP-1, GREATER NOIDA - 201310 CIN : U85110DL1998PLC092494
Ph. : 0120 - 2327222 / 23 / 24, 2327799, 2321111 & 2322222 / 24 Fax : 2322227
E-mail : kailash.gnoida@kailashhospital.com Web site : www.kailashhealthcare.com

DISCHARGE SUMMARY

Patient Name: ANIL BAISOYA
UHID : 1179555 Age: 26-3 Sex: Male
S/o, D/o, W/o : S/O MAMCHAND SINGH MRD No.: IPD/18G/8982
Address: VILL.-SADHOPUR, G.B.NAGAR, U.P
Corporate Name: EAST WEST ASSIST PVT. LTD.
Date Of Admission: 06/10/2018
Date Of Discharge: 11/10/2018 Time Of Admission: 05:28:28
Doctor Incharge: Dr.CHIRAG TANDON Time Of Discharge:

Case Summary :

Admitted with complaint of high grade fever with chills, headache, bodyache, pain in abdomen; no bowel sound and multiple episodes of repeated vomiting since 4-5 days.

O/E - Temperature - 101.6 Degree Fahrenheit
Heart Rate- 112 /minute
Blood Pressure- 130/90 mmHg
SPO2 - 98%.
Chest - B/L clear
Cardiovascular System - S1S2 (+)
Central Nervous System - Clinically NAD
Per abdomen - Soft

Final Diagnosis At Discharge:

Dengue fever with Thrombocytopenia

Provisional Diagnosis at Admission :

Acute Colitis with Gastritis .

Course In The Hospital:

Patient managed with IV antibiotics, IV PPI, cortico steroid, antipyretic, antiemetic and symptomatic; being discharged in stable condition on a follow-up advice. .

Investigations:

STATEMENT OF LAB INVESTIGATION WITH VALUES ATTACHED

On 06.10.2018 - Dengue NS1 - Elisa - 4.50, TLC: 3.48 x10^9/l , Platelet count : 42 x10^9/l, CRP - 22.22mg/L,
ULTRASOUND WHOLE ABDOMEN done on 10.10.2018 - ? Left PUJ obstruction.
On 08.10.2018 - Platelet count : 15 x10^9/l,
On 10.10.2018 - TLC: 19.01 x10^9/l, Platelet count : 65 x10^9/l,
On 11.10.2018 - TLC: 15.15 x10^9/l, Platelet count : 60 x10^9/l,

Treatment Given:

Inj. Monocef 2 gm IV BD Inj Emeset 4 mg IV TDS Inj Oflox 100cc IV BD Inj Pan 40mg IV OD
Inj Paracip 1 gm IV TDS Inj Dynapar 75mg IV BD with 100ml NS Syp. Pan - MPS 2 tsf TDS
Tab. Ebast - Dc 1 tab BD Tab. Microdox - LBX 100mg 1 tab BD
Cap Raciper -D 1 cap BD - empty stomach Tab. Dolowin Plus 1 tab TDS
IV Fluids & other supportive treatment

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Nov. 2019
Name of Village- Sadopur

1. Information on Respondent

Name	Bijendra Sharma
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Tooth Cancer
When do you know (year).	2019
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Ticket

https://server3.ehospital.gov.in/ehospital/opdrepo

117
17/7/19

UHID:2019000864

DELHI STATE CANCER INSTITUTES (EAST) DILSHAD GARDEN

PHONE NO : 011-22135200/22135700 ,

EMAIL: director.dsci@nic.in

EHR ID :2019000204217755

CONSULTING ROOM NO : 4

CLINIC: Clinical Oncology OPD 4 TOKEN NO: 32

DAYS: MON,TUE,WED,THU,FRI,SAT

VISIT NO : 9

LAST VISIT DATE : 12/07/2019

OUT PATIENT RECORD

(RE-VISIT)

C7-15
26/7/19

Name : MR. BIJENDRA SHARMA

Department : Clinical Oncology (CO)

Dept No. : 2019/075/0008103

Date of Registration : 17-07-2019 08:06:23 AM

Unit: CLINICAL ONCOLOGY (OPD)

Billing Type : GENERAL-OR

Mobile No : *******257

Address : SADHOPUR DHOOMEDSO DADRI GAUTAM BODDA NAGAR PIN:203207, UTTAR PRADESH, INDIA

Fees : ₹ 0

Sex : Male

S/O MR HARDAN

Age : 63Y 26D

Email :

Occupation : OTHER

Patient Type : NON MLC

Prepared By : Mr.Kamal Kumar Mahawar

4/32 Doubt chewing (C7B)

Neb.c

= WPI

Adv

i To pantop 40mg
i To MVI
i To deltafix
) 7 days

5/8

Issue CBC/LFT

C1 due on 26/07/19

22/07/19 Tab Prednisolone 20g BD
- To Rantac 150g BD

X5dy

Patient Consent : I, the holder of the above mentioned mobile number , herewith give my consent to share my electronic health information with 'MyHealthRecord', an initiative of Govt. of India. I understand that I can revoke/ withhold this consent through site (https://myhealthrecord.nhp.gov.in)

CBC/LFT

- To Fluconazole 150g OD
- Hexidine gargle 5-6/day
- To Aceclofenac BD x5d

29/07/19

17-07-2019, 08:06

ीमारी को लाईलाज बना देती है। अस्पताल

Questionnaire

Name of the Investigator- Meenu Agrawal
Date of Survey- Nov. 2019
Name of Village- Sadopur

1. Information on Respondent

Name	Raj Singh
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student [✓ Employee] Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Carcinoma tonsil (Dharamsila Hospital)
When do you know (year).	2012
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

DHARAMSHILA
HOSPITAL
YOUR PARTNER IN **CANCER** CARE

DHARAMSHILA HOSPITAL AND RESEARCH CENTRE
Dharamshila Marg, Vasundhara Enclave, Delhi – 110096
T +91-11-43066666, 43066518, 43066530
F +91-11-22617770
E contact@dhrc.in, **W** www.dhrc.in

DISCHARGE SUMMARY (RADIATION ONCOLOGY)

Name: **Mr. Raj Singh**
CR No: **66099**
T. Board No: **S-17544**
Age: **42 Years**
Sex: **Male**
IPD No: **12/02647**
Consultant: **Prof. (Dr.) N. R. Datta, MD, DNB, CCST (UK)**
Diagnosis (Pathology): **Carcinoma Tonsil ($T_1N_0M_0$)**
Site: **Head and Neck**
Admission Date: **31/05/2012**
Discharge Date: **01/06/2012**
Performance Status: **KPS 90**
Associated Diseases : **NIL**
Allergic to: **No known allergens**
Current Admission for : **Supportive care**

CASE SUMMARY:

Mr. Raj Singh, 42 years old male, is a case of carcinoma tonsil ($T_1N_0M_0$) diagnosed at Kailash Healthcare, Noida. He came to our institution on 14/04/2012 with complaints of ulcer in left side. He underwent biopsy on 13/04/2012, which showed carcinoma in situ changes in squamous lining. Slide reviewed was done at our centre which confirmed moderately differentiated squamous cell carcinoma with surface ulceration.

The case was discussed in the tumour board on 17/04/2012 and planned for radical radiotherapy by IMRT. He was planned for external beam radiotherapy by IMRT. He has received EBRT 63.22Gy/29# to face & neck (from 23/04/2012 to 31/05/2012).

Patient was admitted for supportive care. During hospitalization his general condition management with I/V fluids and other supportive medications. Now he is being discharged in a stable condition and advised to continue radiotherapy as schedule.

There is no history of any of the significant co-morbid conditions.

INVESTIGATION MASTER CHART (Those carried out at Dharamshila Hospital):

Haemogram (22/05/2012)
Hb: 15.8 gm/dl TLC: 5700 cells/cumm P.C.: 1.55 lac/cumm

Bio-Chemistry (22/05/2012)
S. Urea : 27 mg/dl S. Creatinine : 0.7 mg/dl
X-ray (chest PA) (18/04/2012): Normal study
Histopathology (16/04/2012): Moderately differentiated squamous cell carcinoma with surface ulceration.

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Nov. 2019
Name of Village- Sadopur

1. Information on Respondent

Name	Chandra Devi
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	Male [✓ Female]
Education	10th ( ) 12th ( ) — Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	[✓ Yes] No Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF (✓) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Acute coronary Syndrome
When do you know (year).	2018 .
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

ASHODA
HOSPITAL & RESEARCH CENTRE

YASHODA SUPER SPECIALITY HOSPITAL
Hospital Reg No – GZB/02146

YHRC/OPD/OP/2018-19/Ver.1

CORONARY/VASCULAR ANGIOGRAPHY REPORT

PATIENT NAME	:- Mrs. Chandra Devi		
REG. NO	:- 381454	AGE/SEX	:- 73Yrs/F
DATE	:- 13/11/2018	CATH No.	:- 8521

DIAGNOSIS:	➢ ACUTE CORONARY SYNDROME

CORONARY ANGIOGRAPHY:

LMCA:	Normal
LAD:	Proximal minor plaque, mid normal, distal normal. Diagonal normal
LCX:	Proximal 20-30% stenosis, distal normal, OM normal
RCA:	Proximal normal, mid minor plaque , distal 100% occluded
LV Angio:	Not done
RENAL Angiography:	Not done
IMPRESSION:	CRITICAL SINGLE VESSEL DISEASE
PLAN:	PTCA + STENT TO RCA

DR. ALOK SEHGAL
MD, DM, FESC
Consultant Interventional Cardiology

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Nov. 2019
Name of Village- Sadopur

1. Information on Respondent

Name	Tej Pal
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student [✓ Employee] Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes [✓ Agricultural wastes] [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability (✓) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Post traumatic painful swelling right hip cause comminuted fracture neck of femur, hypertensio
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes No

Patient copy

DISCHARGE SUMMARY

Hospital Reg. No: GZB/02146

Reg. No. - 394415

DELHI POLICE

Patient Name:- Mr. Tej Pal	**Age/Sex :- 78Yrs/M**
Reg. No. :- 394415	**IP No :- 19/13847**
DOA :- 26/07/2019	**DOD :- 29/07/2019**
Address :- Vill Sadhopur Post Dhoom Manik Pur Dadri G B Nagar	
Consultant: - Dr. Vipin Tyagi MS Ortho. **Dr. Rahul Kakran MCh. Ortho., MS Ortho.**	**Orthopaedics** **Orthopaedics**

Diagnosis:

- **POST TRAUMATIC PAINFUL SWELLING RIGHT HIP CAUSE COMMINUTED FRACTURE NECK OF FEMUR**
- **HYPERTENSION**

Operative Procedure:-

CEMENTED MODULAR BIPOLAR HEMI RIGHT HIP ARTHROPLASTY RIGHT SIDE (ADLAR) DONE ON 27/07/2019.

CUP – 51

HEAD – 28 / 3.5

NECK - + 3.5

STEM – SIZE 2

CENTRALIZER -10.0.

Chief Complaints & Brief history of present illness (at the time of admission):

Patient was admitted with complaints of painful right hip, inability to move the right lower limb following, history of fall at form cause slippage on wet surface associated with restlessness, generalized weakness and malaise.

Relevant past medical/ surgical History:

No H/o Hypertension /Diabetes Mellitus /Chronic Obstructive Pulmonary Disease /Coronary Artery Disease

Relevant family history / Allergies (if any):

Not significant

Questionnaire

Name of the Investigator- Munu Agarwal
Date of Survey- 4th Nov. 2019
Name of Village- Dhoom Manikpur

1. Information on Respondent

Name	Narendra
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee [✓ Business] Housewife

2. Drinking Water related Questions Based on family members

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Bad] Poor Very Poor
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system A septic tank Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Clotting in brain, paralysis
When do you know (year).	2019
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

DEPARTMENT OF HAEMATOLOGY

PatientName	Mr. NARENDRA	**Age**	38Yr 0Mth 22Days
		Gender	Male
UHID	APD1.0011055565	**SIN \LRN**	6365822 \ 2686828
W/BNo/RefNo	Free Ward/4134	**Specimen**	Blood
Printed on	15-OCT-2019 11:14:46 AM	**Received on**	15-OCT-2019 09:26:52 AM
Reported on	15-OCT-2019 10:40:25 AM	**PatSer No.**	DELIP277410
Ref Doctor	Dr.MUKUL VARMA		
UHID			

TEST NAME	**RESULT**	**UNITS**
PT/INR : (Clotting Assay)		
PT Patient		
Mean Normal PT	17.3	
INR	11.8	Seconds
	1.5	Seconds
Biological Reference Interval (PT)	10.0-13.0	
		Seconds

Consultants:

Report Status:Final **Dr.SANGITA RAWAT** **Dr.RASHMI THAKUR**

*** END OF REPORT ***

CHECKED BY : 113276

113276

Rupesh

RUPESH KUMAR DEO

All Lab results should be correlated clinically. For any unexpected results labs may be contacted.

Print

REPORTS ARE GENERATED ELECTRONICALLY..

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Nov. 2019
Name of Village- Dhoom Manikpur

1. Information on Respondent

Name	Mahendri Devi
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	Male [✓ Female]
Education	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student Employee Business [✓ Housewife]

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L [✓ 2.5 L] 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Bad] Poor Very Poor
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear [✓ Turbid] Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes [✓ No] Sometimes
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Severe Gastric problems from 2 Years
When do you know (year).	
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes No

Wd-21 x Post Tab 10:25 am (D.25)

DEPARTMENT OF RADIOLOGY & IMAGING
G. B. PANT HOSPITAL
G.N.C.T. OF DELHI

REQUISITION / INSTRUCTIONS / CONSENT FORM FOR CT SCAN

Incomplete form will not be accepted

Name of Patient	Age	Sex	Ward	Bed No.	Unit	C. R. No.
Maheshi	60	F				2018000/975

Head of the unit: DR. Anil Agarwal OPD GIS | OPD No. | Date 13/6/18

Exact part to be examined: CECT Abdomen/thorax + upper Abdomen

Personal History : History of heart disease / renal impairment / previous surgery infections / allergy to iodinated **contrast/any other** allergy.

LMP (Wherever applicable)

Short Clinical History and duration of illness/Clinical diagnosis:

Concentric thickening of lower Esophageal

BLOOD UREA 27
S. CREATININE 0.7
D-125

Gall

No

Gastro Surgery
GIPMER

Result of Previous Investigations : (Please send hard copy images of previous radiologic .... examination with this form.)

Whether ~~paid or free~~ :

Justification for free recommendation :

20-06-2018

CM NO.

D25

Signature of Referring Consultant with Stamp

Signature of HOD Radiology
(For Free Cases Only)

Signature of M. S. with Stamp
(Foe Free Cases Only)

INSTRUCTIONS

1. Appointment is fixed on ______________ at ______________
2. The patient should be fasting for at least Six Hours / overnight.
3. Charges ______________ to be deposited at Main Enquiry Reception, G. B. Pant Hospital on the same day.
4. **Patients who are on some** medications should take the morning dose with a sip of water.
5. **PAC to be done in G. B. Pant Hospital in Room No** ______________ **/ Ward.**

खाली पेट

C.T. No. 11204-06 **Date:**

P.T.O.

G.B.P.H.

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- Nov. 2019
Name of Village- Dhoom Manikpur

1. Information on Respondent

Name	Khem Chand
Age	Under 18 Between 18 & 30 [✓ Above 30] 65 Years
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate ( ) Post-graduate ( ) —
Occupation	Student Employee — Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L [✓ 2.0 L] 2.5 L 3.0 L 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	Bad Poor [✓ Very Poor]
Generally, how is the smell of your water.	No smell [✓ Foul smell]

Generally, how is the taste of your water.	Tasteless [✓ Bad taste]
Generally, how does your water look like.	Clear Turbid [✓ Dirty]
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes [✓ Industrial wastes]
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required (✓) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta. —	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Paralysis
When do you know (year).	2017
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes [✓ No]
When it was detected (Year).	—
Age of patient.	Under 18 Between 18 & 30 — Above 30
Is there any medical treatment given/ provided to the patient.	Yes No —
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

Caring Lives SHARDA HOSPITAL

No: SH/FMT/NUR/-

ischarge/ LAMA/ Abscond Summary

Discharge DOPR LAMA ☐ Abscond ☐

PATIENT DETAILS: IP No: 264874

Name of the patient: Kheem chand S/O D/O W/O Mr. Ramdhan

Age: 50Y Sex: [✓ M] / ( ) F Ward/Room No: 6th floor ICU

Date of admission: 23/4/17 Date of discharge: Time of discharge: 12:30 PM

Treating consultant: Dr. Vikas Bhardwaj

REASON FOR ADMISSION: H/o sudden onset weakness c̄ fall while in shop, f/b weakness (Lt) UL/LL, slurred speech, trauma to (Rt) eye. X 1 day.

DIAGNOSIS: CVA c̄ (Lt) hemiparesis

OPERATIVE PROCEDURE (IF ANY): —

PATIENT'S CONDITION AT THE TIME OF DISCHARGE: G.C → sick, B.P – 146/90 mmHg, HR – 64/min, SpO2 → 98% on Room air, $E_4V_4M_5$, slurred speech, (Lt) hemiparesis

MEDICATIONS DURING ADMISSION:
- Tab. Ecospirin 150mg OD
- Tab. clopidogrel 75mg OD
- Inj. Monocef 1gm BD
- Inj. Pan 40 i/v OD, Inj. Dynapar i/v Tds, Inj. Mannitol 100ml. tds, Inj. cerevate 60 in 250 ml NS, Inj. Levipil 500mg tds

HISTORY OF CLINICAL FINDINGS: E4V4M5, slurred speech, B/L Pupils reacting, swelling c̄ bluish discoloration over (Rt) eye. (Lt) hemiparesis.

DETAILS OF INVESTIGATIONS DONE: Refer to higher center

IN CASE OF EMERGENCY DIAL: 0120-2529999/777

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 10th Nov.
Name of Village- Achheju.

1. Information on Respondent

Name	Beer Singh
Age	Under 18 Between 18 & 30 [✓ Above 30]
Sex	[✓ Male] Female
Education	10th (✓) 12th ( ) Graduate ( ) Post-graduate ( )
Occupation	Student [✓ Employee] Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	[✓ Yes] No Not sure
If No, rate the quality of water.	Bad Poor Very Poor
Generally, how is the smell of your water.	[✓ No smell] Foul smell

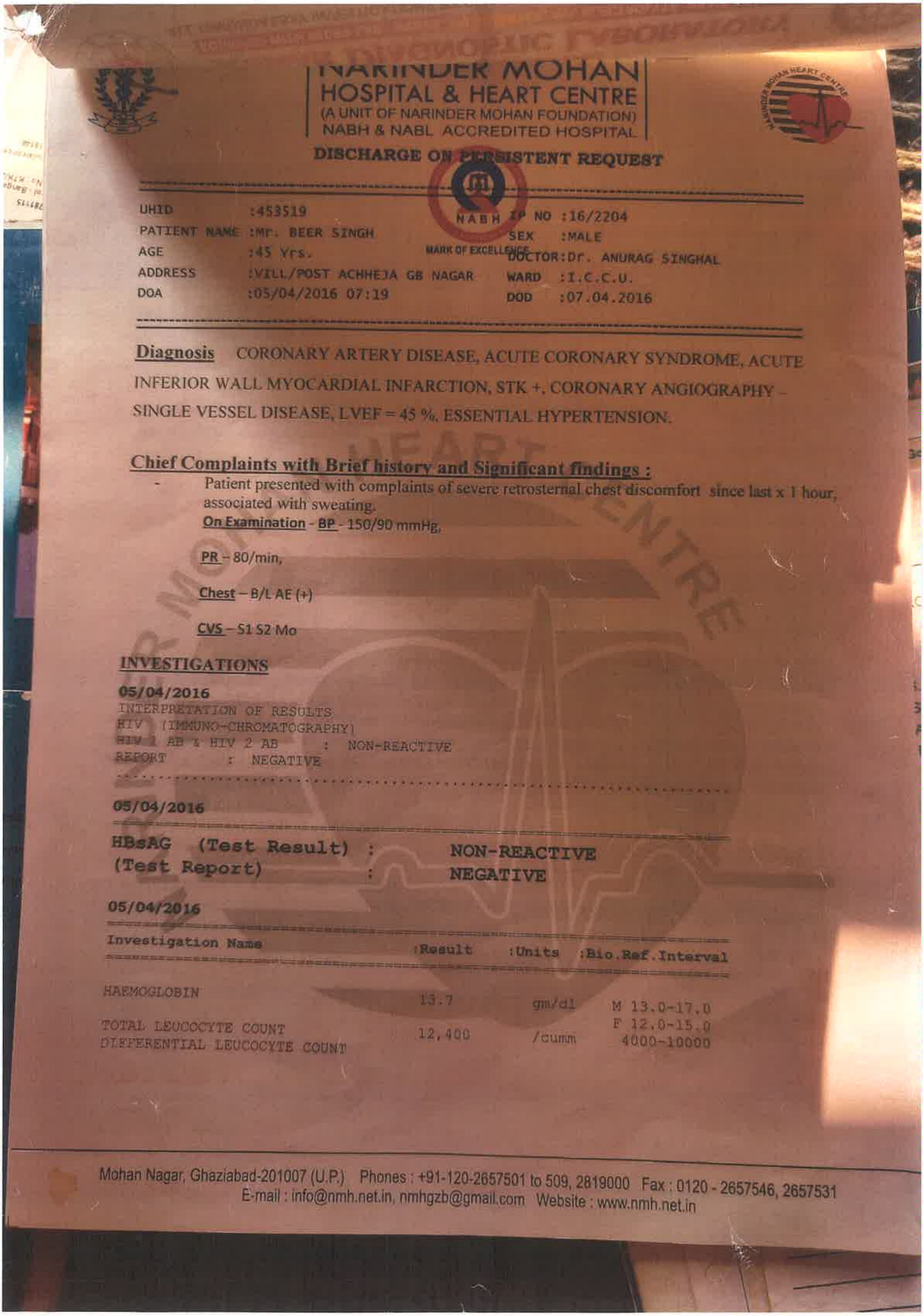
Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	Yes [✓ No]
Do you use mineral water.	Yes No Sometimes
Where, do you think, water of the better quality is found.	[✓ From Handpumps] From Water Taps From bottled water
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes Agricultural wastes Industrial wastes
Have you any water purification device at your home.	Yes [✓ No]
If yes, what type of device used.	Water filter ( ) RO ( ) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required (✓) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Heart Problem, In past he & his wife both had
When do you know (year).	cancer problem but not they have overcome the problem
Do you consider effluent of industries as a problem.	Yes [✓ No]
Is there any cancer patient in your family/village.	[✓ Yes] No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 [✓ Above 30]
Is there any medical treatment given/ provided to the patient.	[✓ Yes] No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]



NARINDER MOHAN
HOSPITAL & HEART CENTRE
(A UNIT OF NARINDER MOHAN FOUNDATION)
NABH & NABL ACCREDITED HOSPITAL

NABH
MARK OF EXCELLENCE

DISCHARGE ON PERSISTENT REQUEST

UHID	:453519	IP NO	:16/2204
PATIENT NAME	:Mr. BEER SINGH	SEX	:MALE
AGE	:45 Yrs.	DOCTOR	:Dr. ANURAG SINGHAL
ADDRESS	:VILL/POST ACHHEJA GB NAGAR	WARD	:I.C.C.U.
DOA	:05/04/2016 07:19	DOD	:07.04.2016

Diagnosis CORONARY ARTERY DISEASE, ACUTE CORONARY SYNDROME, ACUTE INFERIOR WALL MYOCARDIAL INFARCTION, STK +, CORONARY ANGIOGRAPHY – SINGLE VESSEL DISEASE, LVEF = 45 %, ESSENTIAL HYPERTENSION.

Chief Complaints with Brief history and Significant findings :

- Patient presented with complaints of severe retrosternal chest discomfort since last x 1 hour, associated with sweating.

On Examination - **BP** - 150/90 mmHg,

PR – 80/min,

Chest – B/L AE (+)

CVS – S1 S2 Mo

INVESTIGATIONS

05/04/2016

INTERPRETATION OF RESULTS
HIV (IMMUNO-CHROMATOGRAPHY)
HIV 1 AB & HIV 2 AB : NON-REACTIVE
REPORT : NEGATIVE

05/04/2016

HBsAG (Test Result) : NON-REACTIVE
(Test Report) : NEGATIVE

05/04/2016

Investigation Name	:Result	:Units	:Bio.Ref.Interval
HAEMOGLOBIN	13.7	gm/dl	M 13.0-17.0 F 12.0-15.0
TOTAL LEUCOCYTE COUNT	12,400	/cumm	4000-10000
DIFFERENTIAL LEUCOCYTE COUNT			

Questionnaire

Name of the Investigator- Meenu Agarwal
Date of Survey- 10th Nov. 2019
Name of Village- Achheja.

1. Information on Respondent

Name	Bhagwat Singh
Age	Under 18 Between 18 & 30 [✓ Above 30] 80 Years
Sex	[✓ Male] Female
Education	10th ( ) 12th ( ) Graduate (✓) Post-graduate ( )
Occupation	Student Employee Business Housewife

2. Drinking Water related Questions

What is the source of drinking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
What is the source of Cooking water.	Pvt. TW ( ) Govt. TW ( ) Hand-Pump (✓) Public water supply ( ) Bottled water ( )
From how many years are you using that source of water.	5 years 10 years [✓ More than 10 years]
How much of water do you drink per day.	0.5 L 1.0 L 1.5 L 2.0 L 2.5 L [✓ 3.0 L] 3.5L More than 3.5 L
Are you satisfied with the quality of water.	Yes [✓ No] Not sure
If No, rate the quality of water.	[✓ Bad] Poor Very Poor
Generally, how is the smell of your water.	[✓ No smell] Foul smell

Generally, how is the taste of your water.	[✓ Tasteless] Bad taste
Generally, how does your water look like.	[✓ Clear] Turbid Dirty
Do you treat your water to make it safe for drinking.	[✓ Yes] No
Do you use mineral water.	Yes No [✓ Sometimes]
Where, do you think, water of the better quality is found.	From Handpumps From Water Taps [✓ From bottled water]
In your opinion, what is the major cause of groundwater pollution.	Domestic wastes [✓ Agricultural wastes] [✓ Industrial wastes]
Have you any water purification device at your home.	[✓ Yes] No
If yes, what type of device used.	Water filter ( ) RO (✓) RO+UV+UF ( ) Tap attachment ( )
If no, what is reason for it.	Not required ( ) Non availability ( ) Financial issue ( )

3. Questions related to sanitaion facilities

What kind of toilet facility do members of your household usually use.	A piped sewer system [✓ A septic tank] Open defecation
Where do you dispose the livestock excreta.	Dung cakes Nearby drainage Nearby river Open fields

4. Respondents awareness of the water generated problem and Related questions

Is there any health problem due to drinking water.	[✓ Yes] No
What is the problem.	Vocal Cord Cancer
When do you know (year).	2009
Do you consider effluent of industries as a problem.	[✓ Yes] No
Is there any cancer patient in your family/village.	Yes – No
When it was detected (Year).	
Age of patient.	Under 18 Between 18 & 30 Above 30
Is there any medical treatment given/ provided to the patient.	Yes No
Has any action been taken by government/local bodies/ NGO.	Yes [✓ No]

All India Institute of Medical Sciences
.Department of Pathology
Tel: +91-11-26588500/26588700; Fax: +91-11-26588663/26588900

Histopathology Report

Name:	Bhagwat Singh	Acc.No	:0934365
C/O	: Kale Singh	Received on	:2009-12-31
Age	: 70 years	Hosp.Reg.no.	: 115899/09
Sex:	: M	Reporting Date	:2010-01-05

D 4/4
Consultant Incharge: Dr. Rakesh

Material: Operational Specimen /CA left vocal cord

Report:
Received two pieces of soft tissue
True cord measures 1x0.3x0.1cm
True and false cord measures 1x0.3x0.1cm
-Multiple serial sections have been examined from the specimen. There is marked denudation of the surface epithelium, which is identified focally in only two of the five blocks examined. These show severe dysplasia of the squamous epithelium. The sub epithelium area show marked collagensation and fibrosis. skeletal muscle fragment is also identified.
Note: The specimen has been processed in its entiretty.

Senior Resident: Dr Sudheer
Consultant Histopathologist: Dr S. Datta Gupta

Dispatch Date: 2010-01-07
Typed By: Raman Narang
Verified By: Dr Saumya

IMPACT OF AGRICULTURAL, INDUSTRIAL AND DOMESTIC WASTE ON GROUNDWATER QUALITY OF GAUTAM BUDH NAGAR DISTRICT, UTTAR PRADESH, INDIA

Thesis
Submitted to Galgotias University for
the Degree of
DOCTOR OF PHILOSOPHY
in Chemistry

By
MEENU AGARWAL
(Enroll. No. 1509303002)

Under the supervision of

Dr. MEENAKSHI SINGH
Professor in Department of Chemistry
SCHOOL OF BASIC & APPLIED SCIENCES
GALGOTIAS UNIVERSITY
GREATER NOIDA (UP)-201308

Chapter 7

SUMMARY & CONCLUSION

SUMMARY

The present investigation entitled “Impact of Agricultural, Industrial and Domestic waste on Groundwater quality of Gautam Budh Nagar district, Uttar Pradesh, India” was carried out in the selected villages of district. Study was conducted for quantitative analysis of physico-chemical parameters and heavy metals in groundwater samples and waste water samples of the villages. Water samples were collected from eleven villages of district GBN; Duryai, Talabpur, Khera Dharampura, Bishnuli, Achheja, Dujana, Badalpur, Sadopur, Dairy Maccha, Dhoom Manikpur and Badhpura. To assess the effects of waste water on groundwater quality, study area was divided into three zones; Agricultural zone, Industrial zone & Residential zone. Twenty two water quality stations were set up for groundwater sampling. On the basis of survey and field study, thirteen sites were identified for waste water sampling. From each site groundwater and waste water samples were collected in pre-monsoon season (in the month of June) and post-monsoon season (in the month of October) for three consecutive years - 2016, 2017, 2018.

Physico-chemical parameters such as pH, electrical conductivity, total dissolved solids, turbidity, total hardness, calcium, magnesium, sodium, potassium, boron, total alkalinity, chloride, fluoride, nitrite, nitrate, phosphate, sulphate and ammonia were analysed in groundwater samples in the National River Quality laboratory at Central Water Commission, Delhi. Quantitative analysis of various heavy metals (Arsenic, cadmium, chromium, copper, Nickel, Lead, Iron & Zinc) was done using atomic absorption spectroscopy. From the results of physico-chemical analysis, water quality index (WAWQI, GWQI & CCME WQI) and suitability of ground water for irrigation and drinking purposes were determined. To know the effects of waste water on groundwater quality, characterization of waste water originated from agricultural area, industrial area and residential area was also done. Information about the health status of inhabitant of study area was also collected using survey method. A novel approach to remove fluoride ions from aqueous solution using marble slurry was also done through batch experiments. The results of study revealed that characteristics of waste water affects the quality of groundwater.

HEALTH STATUS

- The health survey revealed that inhabitants of villages were suffering from various health disorders
- Major health issue in the study area was carcinogenicity, but it was also noticed that gastro-intestinal problems were common among inhabitants at all the sites.
- The survey revealed that maximum inhabitants blamed polluted water to be responsible for health related issues.

GROUNDWATER QUALITY

In agricultural zone of study area, groundwater have higher concentration of boron, nitrate & phosphate. Ionic concentration in groundwater decreased in post-monsoon season however chloride strength increased after rain fall. Among the analysed heavy metals, iron concentration was found high in groundwater samples of agricultural zone. The extensive use of fertilizers for better crop yield was responsible for elevated content of boron, nitrate, phosphate, chloride and iron. Water quality index of samples showed that groundwater quality at Duryai station was unfit for drinking. On the basis of irrigational parameters, groundwater quality of agricultural area was safe for irrigation. Analysed agricultural waste water samples had high content of ammonia, potassium, nitrate and iron. These analytical results reflect that groundwater quality of agricultural prone areas was affected by agricultural runoff.

In industrial zone of study area, groundwater was hard and heavily contaminated. High ionic concentration of calcium, sodium, potassium, fluoride, chloride and sulphate was obtained in samples collected from industrial area. Metal content of samples of industrial area was very high. Mean values of arsenic, chromium, copper, nickel, lead and zinc were maximum in groundwater samples of industrial zone. On the basis of WQI, groundwater of Bisrakh Road and Achheja water quality stations was not fit for drinking purpose. Groundwater of industrial area was highly saline hence unsuitable for irrigation. Waste water samples of industrial areas have excessive ionic concentration and high content of analysed metals (As, Cr, Cu, Pb, Ni, Fe & Zn). The specific occurrence of metal ions in waste water samples clearly indicates the effect of effluent of nearby industry.

Groundwater of residential zone was highly alkaline and have high concentration of magnesium, fluoride, nitrite and ammonia. High cadmium content was obtained from the groundwater samples of Dhoom Manikpur. Effluent of cement factory, present in Dhoom Manikpur adversely affected groundwater quality. Water quality index data revealed that all the stations in residential zone (Sadopur, Dhoom Manikpur, Dairy Maccha & Badhpura) have groundwater quality unfit for drinking. Irrigational water quality of residential zone was comparatively poor than industrial and agricultural zone. Domestic waste water samples were very turbid with high alkalinity. Mean value of magnesium, fluoride, nitrite, phosphate and cadmium were maximum in domestic waste water samples.

DEFLUORIDATION OF AQUEOUS SOLUTION

In present study, marble slurry is proved as an efficient adsorbent for the removal of excess of fluoride from aqueous solution. Under optimum conditions, its fluoride removal efficiency was obtained upto 89.3%. As marble slurry is produced as a by-product from marble industry, its use in defluoridation is cost effective. Marble slurry also has some ecological threats so its reuse protects the environment.

CONCLUSION

The results of study revealed that groundwater of district Gautam Budh Nagar was loaded with high ionic content as well as heavy metals. The waste water samples contained high value of pH, electrical conductivity, total hardness, total dissolved solids, cations, anions, and heavy metals in both seasons. Characteristics of waste water greatly affected groundwater quality. Leaching of hazardous chemicals present in effluents of steel-iron industry, rice mill, paper industry, fabric dyeing industry added a significant amount of pollutants in ground aquifers. Results of physico-chemical analysis, metal analysis and water quality index revealed that groundwater of agricultural zone was suitable for drinking and irrigation. Groundwater of industrial zone was highly polluted and level of pollutants depend upon the type of industry present in the region. Groundwater quality of residential zone was unfit for human consumption and irrigation. Appropriate measures need to be taken immediately otherwise contamination can reach to ground aquifers of other regions. Results of seasonal variation in quality parameters showed that recharging of ground aquifers in monsoon season, lessened the contamination upto a great extent.

RECOMMENDATIONS

- On the basis of current study, regular water quality monitoring, water quality management and restoration programs should be conducted in study area.
- In agricultural prone areas, reckless use of fertilizers should be discouraged.
- Farmers should be encouraged to take the benefits of soil health card scheme promoted by Ministry of Agriculture and Farmers Welfare.
- Treatment of waste water, generated in industries, is required before dumping it.
- Development of appropriate sanitation facilities is required in residential area.
- Segregation of waste at the source level so as to ensure that the reusable/ recyclable and metal oriented waste is not dumped.
- Treatment of groundwater is requisite before it is supplied to the water distribution system.
- The study concluded that awareness campaigns about the deteriorating quality of water should be conducted by the government through various conventional means and social media.
- In problematic areas, effective management and remedial measures for groundwater quality should be applied.
- Policies will be prepared on state and national level to avoid further deterioration of groundwater quality.

SCOPE FOR FUTURE WORKS

- Model can be developed on the basis of relation between the geographical profile of the study area and groundwater contamination.
- Study can be extended for microbial quality of water.
- Further in the problem zones, pollution sources can be monitored and new treatment techniques can be developed.
- Studies can be conducted regarding the possibilities of waterborne disease in the area.